THE BIOLOGY OF THE SEASONS

LIFE OF A TARN: WATER-SPIDERS, TADPOLES, NEWTS
(I)
(*FRONTISPIECE*)

THE BIOLOGY OF THE SEASONS

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PREFACE

THE aim of this book is to get at the gist or inwardness of the seasonal drama, without going too minutely into the details of the successive scenes. In other words, it is a study of certain biological aspects of the seasons, not in any sense a naturalist's year-book, that I have essayed.

The book is intended for all who enjoy the pageant of the year and the drama of the seasons, and who see something of the import of the annual analysis—as if through a prism—of the evolutionary flow of things. There is some reason to believe that Man was helped to find himself long ago by his discovery of the Year—with its educative object-lesson of recurrent sequences and long processions of causes. Similarly to-day we may be helped to live on more equal terms with Time by getting back into close and appreciative touch with the march of the seasons. But if that touch is to be natural to men of to-day, it must be scientific as well as practical and emotional. Hence this contribution to a Biology of the Seasons. It is hoped that it may be of particular service to those who have to conduct courses of Nature-Study, which should certainly follow the seasons as closely as possible.

I am well aware that this series of studies and sketches —some more impressionist, some more analytic—cannot be more than illustrative of the biological outlook on the seasons. For it is a big problem to try to detect the seasonal punctuation of individual development and of

racial evolution, to trace out the inter-relations of organic rhythms and external periodicities. The ideal would be to study the organismal drama of the year with the sympathetic feeling of the old naturalists, such as Gilbert White, with Darwin's dominant sense of correlation and evolution, and with Spencer's grasp of the unity of science! No one knows better than myself how far my reach has exceeded my grasp in this fascinating inquiry. Perhaps, however, the book may give a stimulus to the serious study of Phenology or Season-Lore.

I am not forgetful that many naturalists have studied the life of plants and animals in its varied seasonal expression, and that many of them have found the study so rich in reward that they have sought to attract others to it. From Gilbert White's evergreen *Natural History of Selborne* to Professor L. C. Miall's *Round the Year*—to mention two books remarkable in their accuracy, insight, and sincerity—there has been a succession of Naturalist Year-Books. But the aim of this volume is at once more general and more intimate. It is an attempt to get at the underlying principles.

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BIOLOGY OF THE SEASONS

INTRODUCTORY

BY the Biology of the Seasons we mean the study of the phenomena and phases of life—in plants and in animals—in relation to the time of year with which they are especially connected. That this is a very natural—perhaps *the* most natural—method of biological study will be at once evident to many. Perhaps it would be evident to all, were it not that many of us, dwelling in cities and becoming careworn, have lost much of that interest and delight in the seasonal drama which is characteristic of country-folk in happy conditions. Not that these country-folk are given to talk much about it, a silence which has given rise to the extraordinary idea that the delights of the country were discovered by the town.

The old-fashioned appreciation of the seasons was expressed, as we all know, in many fairy tales and myths, such as those of the Sleeping Beauty and of Proserpina, and it needs but little insight to see that these are really "fairy tales of science"—often, indeed, of surprising accuracy. In this connection, it may be noted that naturalists owe thanks to the poets for consistently helping to keep the appreciation of the seasons alive. From Homer to Horace, from Gawain Douglas to Thomson's "Seasons," from Tennyson to Meredith's "Lyrics and Ballads of the Earth," there is a

glorious succession of seasonal poetry. Here, as in many other respects, poetry may instruct her stern and sometimes rather superior sister—Science. But as the years go by, will it not become plain that the poet, the physiologist, and the philosopher (shall we not include the theologian ?), are trying to say the same thing in different words ?

That the method of seasonal biological study is educationally sound is best proved by experiment. But it is perhaps enough to ask the simple question : *What kind of scientific lore concerning living creatures would we most naturally teach our children in Spring?* This is a sensitive touchstone of educational validity. Surely our tale should be of the opening buds and the early flowers, the return of the birds and the quickening of the chrysalids. Similarly in autumn, we should inquire into the withering leaves, the ripening fruits, the scattering of seeds, the farewells of the birds, and the general sinking into sleep. Only thus can we lessen the gap between learning and living ! And every year, since the inquiry is not easy, we should return with more penetrating questions to watch the endless pageant of the seasons, studying each thing "in its time" when it is beautiful. The seasonal order of studying "animated nature"—at first along Natural History lines and later as a biological inquiry —is practically convenient, and it keeps us in harmony with out-of-door interests, both of work and of play ; but there is an even deeper vindication. The seasons have subtle influences on human life, and the natural phenomena of the outer world will be studied *with most organic sympathy* at the time of their occurrence.

> "Four seasons fill the measure of the year ;
> There are four seasons in the mind of man."

The older naturalists—before Darwin's day—made many careful pictures of the life of plants and animals as it is lived

in Nature. The indefatigable patience, the keen observation, and the sympathetic insight of many of these pre-Darwinian naturalists must remain as models to which in these later days, with improved methods, we try to approximate. Gilbert White's "Selborne," above all, remains evergreen. But the old records are for the most part contributions to Natural History rather than to Biology. To most of their authors there was wanting the biological key which Darwin first taught men to use. We mean not merely the idea of organic evolution, that the present is the child of the past, though that is indeed the "Open Sesame" of Nature—but other biological conceptions as well—of protoplasm and its changes, of the rhythms of life, of effective response to external stimuli, of the correlation of organs and of division of labour, and of the correlation of organisms in the web of life.

The difference between the old naturalists and the new, which came partly through Darwin's influence and partly because the time was ripe, may be readily perceived if we compare, for instance, the older *naturalist-travellers* with the new. No one can dispute the virility—sometimes rising to greatness—of the work done by Thomas Pennant, Peter Pallas, Gesner, Humboldt himself, and the crowd of more specialist-travellers who followed these; but there is a difference *in kind* between their results and those embodied in Darwin's *Voyage of the Beagle*, and in other narratives of naturalists' journeyings—by Wallace, Bates, Belt, Moseley, Hickson, Hudson, Rodway, Scott Elliot, Alcock, and some others. Biological ideas have become dominant; analysis has become more penetrating; the pictures have a broader perspective and a deeper insight. Through and through we feel that the travellers are dealing, not merely with interesting things that they are delighted to describe, but with an evolutionary drama that they are trying to understand.

Similarly we find in modern studies of plant and animal life in our own country—of the shore-fauna or of the flora of lakes, of birds and their nests, or of flowers and their visitors—that the biological note is becoming more and more dominant. In some cases it is obvious that the evolution idea forms the unifying centre of the study. In the same way, it is by an emphasis on underlying principles that a Biology of the Seasons should differ from a Natural History of the Year. And that is our aim in this book.

External Periodicities

The physical fact of most importance in connection with the biology of the seasons is the familiar one—that the sun is our main source of energy, and that, according to our seasonal relation to it, we get varying amounts of heat and light. With this primary relation are associated many secondary seasonal variations,—in rain-fall, barometric pressure, winds, tides, and so on. The Biology of the Seasons has for its central task an inquiry into the adaptations of living creatures to the external periodicities, which we sum up in a rough, popular way in speaking of Spring, Summer, Autumn, and Winter. The astronomical division of the year is familiar :—From the Vernal Equinox to the Summer Solstice ; from the Summer Solstice to the Autumnal Equinox ; from the Autumnal Equinox to the Winter Solstice ; from the Winter Solstice to the Vernal Equinox. But this precise division of the year is not very useful biologically, and some compromise must be accepted.

Thus, for practical purposes, we may agree that in North Temperate regions, Spring is late March, April, and May ; Summer is June, July, and August ; Autumn is September and October ; Winter is November, December, January, February, and part of March. The basal fact,

from the biological point of view, is that the ratio of heat-supply in summer to that in winter is as 63 : 37.

Vital Rhythms

Since ever physiology had any meaning, men have been aware of the twofold process of waste and repair that goes on in the living body. On the one hand, there are assimilative or constructive chemical changes, as the result of which complex substances are built up; on the other hand, there are disruptive or destructive chemical changes, as the result of which complex substances are broken down. The two sets of processes together include most of the important chemical changes in the body, which are summed up in the term metabolism. There is general agreement that, *from the chemical point of view,* "the life-process consists in the metabolism of proteids," as Professor Verworn puts it.

Generalising from his studies on colour sensation, Professor Hering was led to regard living (physiologically considered) as an alternation of two kinds of activity, both induced by stimulus, the one kind of activity tending to storage, construction, assimilation of material; the other kind of activity tending to explosion, disruption, and disassimilation. Certain cells of the liver, for instance, are kept toned-up to be makers of animal starch or glycogen—that is assimilation. But when the muscles of the heart are kept toned-up to be continually oxidising carbon-compounds in the muscle-substance—that is disassimilation.

Generalising from his studies on nervous activities, Professor Gaskell was also led to regard living (physiologically considered) as an alternation of two processes, one of them a stimulated running-down or disruption

(katabolism), the other a more autonomic winding-up oi construction (anabolism).

But without going further into interpretations, which remain uncertain, we may say that all physiologists are agreed about *the fact*, that there is in all living a twofold process of waste and repair, of discharge and restitution, of activity and recuperation. And it is the preponderance now of the one, and again of the other, that constitutes the fundamental rhythm of life. As it is said in Ecclesiastes iii. : " To everything a season . . . a time to break down and a time to build up . . . a time to cast away stones and a time to gather stones together . . . a time to get and a time to lose . . . a time to keep and a time to cast away."

Besides the alternation of predominant anabolism and predominant katabolism, though ultimately dependent on it, there are numerous periodicities in the life of organisms. The growth of the embryo is sometimes markedly periodic. Thus Dr. A. Fischel says of duck-embryos, that " the growth of the whole length of the embryo as well as that of the several regions of the body is *periodic*." It is said of some very simple organisms that they can continue to move only as long as a certain substance within them holds out ; when that is used up there is no movement possible until after a period of nutrition. They have to be re-charged. So in nerve-cell and muscle-cell, wonderful engines as they are, there is a necessary limitation to the output. Rest *must* alternate with work. We see a similarly fundamental periodicity in the see-saw between nutrition and reproduction, between vegetating and flowering. " A time to embrace, and a time to refrain from embracing."

Our point is that living creatures are inherently predisposed to be rhythmic, and that on this predisposition

the external periodicities operate. The fundamental problem of the Biology of the Seasons is to trace the relations between the external periodicities and the vital rhythms. Our central thesis is that *life is rhythmic, and that it is punctuated by the seasons and by other external periodic influences.*

Let us take a few illustrations. Many vegetable cells, such as simple Algæ, feed during the day and divide at night. The deeply rooted inherent contrast between nutrition and reproduction is externally punctuated. Flowers open and shut, wake and sleep, periodically. Biological virtuosos with leisure have made "floral clocks." Some flowers are intermittent even in their fragrance.

The lines of growth on shells and on some bones indicate periodicity, like the rings of growth on a tree, or the rings on the rattlesnake's rattle, and this self-registering of alternations is widespread—as the four illustrations may suggest—in organic nature. In most cases it seems that the punctuation is from without, while the necessity of the alternation is from within. We can read summer and winter on the scales and otoliths of fishes, just as we can read day and night on a bird's feather. The increase to the scales in the summer period is different from that in the winter period, and the daily variations in the bird's blood-pressure are sometimes registered, when feathers are a-making, by the beautiful cross-bars. There is periodic waxing and waning of venomousness in snakes, and there are well-known periods in some diseases. Even the times of cock-crowing sometimes correspond to external periodicities of temperature.

Some of the correlations between external and internal changes admit of very direct interpretation; thus we understand at once that green plants are intensely active during the day and relatively restful at night, the hidden

process of "photo-synthesis" being necessarily at a standstill in the dark.

That is a simple case, but many correlations are due to a circuitous nexus, as in the case of the relation between the amount of sunshine in Spring and the abundance of mackerel around our coasts. Mr. G. E. Bullen finds that for the years 1903–1907 there appears to be a correlation between the number of mackerel taken during May and the amount of Copepod plankton, upon which the mackerel feed, taken in the neighbourhood of the mackerel fishing grounds during the same month. Mr. W. J. Dakin shows that the food of the Copepods consists largely of the vegetable organisms of the plankton, such as diatoms, and of Infusorian-like organisms called Peridinidæ. But the production of this microscopic plankton, the "stock" of the "sea-soup," depends partly on the composition of the sea-water, partly on the temperature, and partly on the amount of light available. There seems to be no correlation between the surface temperature and the abundance of mackerel, but Dr. E. J. Allen of the Plymouth Marine Laboratory, who has brought all these facts eloquently together, has shown that there is a real correspondence between the amount of sunlight and the catches of mackerel.

In some cases the correspondence between external events and vital events seems unmistakable, and yet we cannot understand the connection. Thus Professor Kofoid has brought forward some striking evidence of a correlation between lunar changes and quantitative changes of river plankton, which seems even more mysterious than the connection between the full moon and the excitement of lunatics, or between sun-spots and trade-strikes.

There are several correlations as certain as that between the Spring sunshine and the supply of mackerel at Billings-

gate, in regard to which we must confess that we do not see the rational interpretation. And the case of the mackerel leads us to the result—very valuable in interpretative science—that a genuine correlation may be established *through a circuitous nexus.* It may turn out, in spite of the phrase "all moonshine," that the moon causes vital tides.

In the case of long-established correlations between external periodicities and internal vital changes, it seems that the former may come to be needed only as liberating stimuli or trigger-pullers. The internal periodicity may become, in the course of ages, so thoroughly ingrained constitutionally, that it requires only an appropriate touch at the appropriate time to keep the business going smoothly. In this connection we may refer to Professor Semon's pretty experiment with young acacias (*Albizzia lophantha*). They had never been exposed to the normal alternation of day and night, to which their race responds by expanding and closing the leaves. Semon exposed them to artificial days and nights of six hours' or twenty-four hours' duration, but the plants exhibited the twelve-hours' cycle quite unmistakably—though just a little altered. After this experiment, Semon exposed his plants to continuous darkness or to continuous illumination. The twelve-hours' cycle still manifested itself for a time, but gradually became indistinct. Here we see the ingrained hereditary periodicity struggling against inappropriate stimuli—inappropriate to an extent that could hardly ever occur in nature.

It is said that the tropical African mudfish (*Protopterus*), taken to North Europe and kept with abundant water, tends to become dormant at what corresponds to the African dry season, when it normally goes to sleep for half the year. It is said that migratory birds in cages become restless at

the proper season though they are living in conditions of great comfort. In such cases the internal periodicity seems to assert itself even in the absence of the normal stimulus.

Curves of Life

It is useful, then, to think of the course of life as an ascending and descending curve—sometimes like a semicircle, sometimes like an ellipse halved lengthwise, sometimes like a parabola, when seen from a distance. If we get near it and peer closely into it, we find that the curve has endless minor irregularities, like a pulse tracing or like a barometer tracing. On the whole, however, there is an up-grade, steep or gradual, from egg to embryo, from embryo to larva, from larva to a miniature of the adult, from this to the adolescent, and thence to the fully developed organism ; then there is a crest, long or short, of maturity ; and then there is a down-grade, marked by decreasing vigour, sinking down through senescence to the nadir of death.

We rather like to think of the complete life as a parabolic curve—without beginning of days or end of years—for who, in face of the facts regarding ancestral inheritance and the continuity of the germ-plasm, can insist very dogmatically on beginnings or endings ? What we call the individual is part of a larger life. It is like a particular form of wave in the sea, individualised for a brief moment, but only intelligible as part of a great system of currents.

Let us keep, however, to the broad facts. The creature rises from the *vita minima* of early embryonic life to the vigour of adolescence and to the full strength of maturity. At its limit of growth it often reproduces, and this is, as often, the beginning of a descent. Quickly or slowly, but

surely, it sinks on the down-grade to the *vita minima* of senescence, which ends in death. The contour of the curve differs, of course, for different kinds of creatures, but the broad fact of cyclic development remains.

In the case of annual plants or annual animals, our problem is to compare the trajectory of the life-history with the curve that serves to register graphically certain big physical facts of the year, notably the distribution of solar energy. And when the plant or animal lives for more than a year—it may be for stretching cycles of years like the North American Sequoias, one of which spanned the whole period from the birth of Aristotle to the death of Darwin—we have to collate the periodicities of the year with minor undulations on the main life-curve.

The Living Creature and its Surroundings

In its broadest statement the central problem of the Biology of the Seasons is to investigate the relation between the changeful organism and its changeful environment within the period of the year. But this relation is manifold, not simple, and it obtains in various degrees of directness.

We do not know what life in principle is, but we may describe living as action and reaction between organisms and their surroundings. This is the fundamental relation—the absolute dependence of living creatures on appropriate surroundings. In fact, the two are inseparable. The living creatures are real just in the same sense as their surroundings are real, and function is but a descriptive term for the dynamic relations between them. Thus we cannot abstract the living creatures from their sphere of essential surroundings. When we try to do this they die—even in our thought of them, and our biology sinks into necrology.

Huxley compared a living creature to a whirlpool in a river; it is ceaselessly changing, yet always apparently the same; matter and energy stream in and stream out; it is the unessential flotsam that has most permanence; the whirlpool has an individuality and in varying degrees a unity, yet it is wholly dependent upon the surrounding currents. One may push the whirlpool metaphor too far, so as to give a false simplicity to the facts, for there is no denying that when vital whirlpools began to be, there also emerged what cannot be discerned in the crystal or in the dewdrop—the will to live, a capacity of persistent experience, and the power of giving rise to other lives. The vital whirlpool is a creative agent as well as a creature. To ignore this is to attempt a falsely simple natural history. But what Huxley's metaphor of the whirlpool does vividly express is a great commonplace and a great truth—the fundamental dependence of living creatures upon their surroundings. We cannot understand either the whirlpool or the trout apart from the stream.

A very important corollary of this fundamental everyday relation has to do with development. In some way which we cannot picture, the fertilised egg-cell contains the potentiality of a particular living creature—a tree, a daisy, a horse, a man. If this inheritance is to be realised there must be an appropriate environment, supplying not merely food and oxygen, but essential liberating stimuli of many kinds. Without this "nurture" the inherited "nature" can achieve nothing. The development of every character implies the interaction of the two sets of factors—the internal organisation and the external sphere of influences.

Since the "nurture" that plays an essential part in the development of "nature" is changeful, it often induces *modifications* in the young organism, and this modifiability

by external influences is continued throughout life. Different creatures differ greatly in their susceptibility, but they are all in the grip of a complex environment which acts on them in rough or in subtle ways. Whether we think of the seasons or the climate, the soil or the sea, we find that this environment is intricately variable. Indeed every kind of plant and animal is continually passing into a new environment of chemical, mechanical, dynamic, and animate influences which play upon it. All through the ages this has been going on; living creatures have been, as it were, ceaselessly passing over a series of anvils on which the hammers of external influences play, with tunes of ever-increasing complexity. It is evident that every increase in the fulness of life implies additional complexity in the incidence of external forces. Every increase in locomotive power, for instance, increases the multiplicity and multiformity of action and reaction between the animal and its surroundings.

Part of the Biology of the Seasons, then, consists in studying the dints made on living creatures by something unusual in the play of the inanimate hammers—by some change in the surge of the wave, the swish of the wind, the salinity of the water, the composition of the soil, the humidity of the air, the temperature, the illumination, and so on. The organism is continually running the gauntlet of environmental forces, which may induce responses or modifications. These may be defined as structural changes in the body of an individual, directly induced by changes in function or in environment, which transcend the limit of organic elasticity, and thus persist after the inducing conditions have ceased to operate. Thus the tanning which follows prolonged sun-burning in the Tropics may persist as a permanent modification throughout the rest of the individual life.

But besides seasonal *modifications*, we have to recognise a possibility which is only beginning to be studied, which adds to the complexity of the biological problem—the possibility that external changes may serve as *variational stimuli*, inducing germinal changes which find expression in the next generation.

The ingenious zoologist, Professor Semon, has recently propounded a theory which may be noticed in this connection. It is called the theory of the "Mneme," and it is based on the fact that when living matter is affected by a stimulus its quality cannot be the same as it was before the stimulus. There is some residual effect, which Semon calls an engram. All stimuli, Semon believes, produce engrams, and the sum of the engrams of a living creature is its "Mneme"—its organic reminiscences we may almost say. The "Mneme" may have particular importance in cases where penetrating stimuli, like those of the seasons, recur periodically, revivifying old impressions and re-enforcing them.

Some biologists believe that this line of thought is useful, and that by following it we may come to understand how the results of experience may be treasured from generation to generation, although individually acquired modifications in the ordinary sense are not entailed. The effects of a stimulus may radiate through the organism, may pass from part to part by nerve paths and protoplasmic bridges, and may in some cases reach even the germ-cells in their recesses, thus influencing the next generation. This remains a speculation.

But apart from possibilities of inheritance, it seems to us safe to say that the ceaselessly changing march of the seasons brings to organisms—which are agents, not mere pawns in the game—new possibilities of creation, of garnering experience, of trading with time.

We have lingered over the relations between living creatures and their surroundings, because this is in great part the subject of the Biology of the Seasons, and because the influence of surroundings on the creature is often spoken of too glibly as if it were one and simple, whereas it is manifold and complex.

BOOK I.—SPRING

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IMPRESSIONIST SKETCH

"GERMINAL, Floreal, Prairial"—these were the names given to the Spring months at a famous Spring-tide, over a hundred years ago, when men in the April folly of their hearts dreamed that they could make all things new. But the new names proposed, which are certainly not without merit, have passed away with many other things; the old names remain, and perhaps they are well enough. They are certainly better than those of the last section of the year, where the art of naming that began in Eden touches low-water mark. The old names are well enough, we say, for is not March a month of warring, of elemental strife, when the sun gains his well-assured annual victory? And is not April indeed the month of opening? The earth that has been frost-bound opens, and the seedlings lift their heads, drowsily nodding, "nutating," as the botanists put it, bending and bowing to the different points of the compass, swithering between the peace of automatism and the pleasures of sentiency. The buds open, and the leaves unfold, a literal "*evolutio* of inherited potentialities expressed under an appropriate environment of liberating stimuli." The spring flowers open and the newly awakened insects visit them. Of a surety, April is the time of *opening*—of the earth, of the seeds, of the buds, of the flowers, of the eggs, and of the womb, of the song of birds, and of the heart of man.

As one of the simple poets of the seasons said—

> "Up!—let us to the fields away,
> And breathe the fresh and balmy air;
> The bird is building in the tree,
> The flower has opened to the bee,
> And health, and love, and peace are there."

Natures's optimism in the Spring-tide is irresistible; the frost cannot stand before the sun. They bound Dionysus fast, but they might as well have tried to stop the rush of sap in the vines covering the hillside. Zagreon they cut in pieces, but he had to be put together again. Gloomy Dis robbed Demeter of her Proserpina, but did she not come again out of Hades? Baldur the beautiful was slain with the wintry mistletoe, but if he did not come to life again, he was at least well avenged by another member of his inexhaustible race. Dornröschen was pierced by a cold spindle, but she slept and did not die, and the Prince kissed her awake. Likewise, in the torrid zone, where life is conquered by heat, not by cold, the Phœnix was consumed, only to rise triumphant from the ashes of his burning. Do not all these images mean much the same thing, that life is insurgent and indomitable? The northern Winter seems to slay, but the hurt is seldom beyond Spring's curing. Winter seems to put out the fires of life, but the Spring breeze fans them into rampant flame. The corn of wheat that seems to die brings forth much fruit. The Spring's gospel of resurrection is irresistible.

The Winter is over and gone, but it has been long and hard. Month after month Demeter has been mourning in our midst—a Mater Dolorosa—seeking her lost child everywhere, often angry and terrible, often plaintive and tearful, veiling her lost beauty but not her deep distress. Yet all the while she has shown the strong virtue of maternity. For, explain it who will, she has nursed, without food or

drink, the tender life of Keleos, and the youth flourishes bravely. Does this old story not refer to that commonplace of the biology of Winter that Mother Earth has been a careful nurse of the seeds committed to her charge? That the seeds are "adapted" to the Earth is familiar to all, but in common honesty we must recognise that without putting herself about the Earth looks after them well.

In any case, we observe in Spring that the rise of temperature has quickened the seeds, prompting the formation of nuclein compounds and the division of cells (which organic growth implies). Ferments have dissolved the hard stores of reserve-material into soft nutriment. The very minions of Death—the Bacteria—have helped to loose the bands of birth, and the seedlings are rising from the ground. For now the anger of Demeter is stayed, Proserpina has returned from the kingdom of the dead, mother and daughter rejoice together. And in a world where all is so wonderful, "so full of death, so bordering upon heaven," is there anything so wonderful as this meeting of life and death, as this raising of what we call dead into what we call living, as this power that green plants have to win the sun's aid, that they may, by secret alchemy, transmute the beggarly elements of water, soil, and air into the bread and wine of life? We can understand the dying Keats saying that of all things the most beautiful was the growing of the flowers—"the growing of the flowers." And there will certainly be reason for deep regret if the study of the Biology of the Seasons, in leading students to a theory of "photo-synthesis," loses the vision of the returning Proserpina.

The great god Pan is with us again, tangibly but never visibly. We feel him in the warm Spring breeze, and everywhere we hear his merry pipes. Now he is among the rustling withered reeds, quickening them to leafage, and setting the birds a-singing; now he is over the rippling lake,

swifter than any swallow. Yesterday we heard him in the glen, good-humouredly tossing a naughty cuckoo's tidings to one of her many lovers; to-day he roams by the lake-side, and sets the daffodils dancing. Their exuberance and gracefulness are typical of the Spring, as is their "abandonment" when the breeze caresses them, and some are near enough the water to be mirrored there.

But Pan's pipes are not always merry. He sighs eerily through the gorge and among the crags, where Boreas, in the winter, so ruthlessly slew Pitys, whom Pan loved. What a terrible destruction that was; acre after acre of lusty trees, brought to the ground, like legions before some inevitably victorious, because continuous, horde of barbarians. We are remembering some of the Perthshire woods, after the terrible storm that swept the Tay Bridge away.

See the God: who ever did? But do we not catch in these floating spider-webs the fringe of his flowing robe? Men saw it of old, for they called it Godsamer.

It is difficult to distinguish the various voices in the Spring medley, and our myths are apt to get mixed; now it is Pan, and again it is the Pied Piper who gathers life in his train; now it is Zephyrus playing with Chloris, and again it is Orpheus, whom none can resist. But the facts are plain, and that is what most concerns us; the birds, who went forth before the winter, changing their season in the night, and "wailing their way from cloud to cloud down the long wind," have returned rejoicing with Spring in their voices. Whether it be the naughty cuckoo, who has hoaxed all the poets, or the dove, who is morally not much better, or the virtuous stork on the roof-trees, or the nightingale melodious, or the lark at heaven's gate—everywhere from the orchestra which gathers strength every day, we hear but one *motif*, "Hither, my love, here; here

I am, here ; the winter is over and gone, arise, my love, my fair one, arise and come away."

Dornröschen, the Sleeping Beauty, has been kissed awake again. One after another had striven in vain to win a way through the barriers which encircled the place of her sleeping ; but at length the Prince and Master came, to whom all was easy—the sunshine of the first Spring day. And as he kissed the Beauty, all the buglers blew, both high and low, the cawing rooks on the trees, and the croaking frogs by the pond, each according to his strength and skill. All through the palace there was such a reawakening : of the men-at-arms,—we call them bears and hedgehogs ; of the night-watchmen, known to us as bats ; not to speak of the carpet-sweepers, like the dormice and hamsters—all were reawakened. The messengers went swiftly forth, we are told, the dragon-flies like living flashes of light ; the bustling humble-bees, making a good deal of fuss, but refreshing themselves considerably at "The Willow Catkins" by the way ; the moths flying softly by night on secret service. How accurate the old stories are : "The scullery-boy got a long delayed box on the ear when the cook awoke" ; I saw the wood-snail draw in his horns as the thrush swept swiftly by.

These Spring days are the days of youth—of seedlings, buds, and fresh blossom, of tadpoles, nestlings, and lambkins : of which, as of children, there are two thoughts which we cannot help thinking.

The first is a thought of Easter, of the forgiveness of Nature, of its infinite power of making a fresh start. In Autumn we saw the vine robbed of all its leaves—transfigured in their dying—and hard-bound by the frost ; but Dionysus smiled at his captors, and now the tender vines put forth a sweet smell. We saw the sloe in winter, bare as a skeleton in the desert, but black ; we see it now covered

with white blossom, which we almost mistook for snow still unmelted. We saw the hedger strip the hawthorn till it was pitiful in its nakedness ; we see it now covered with bursting buds, and it will soon be the time of May-blossom. From amid the withered leaves the wood-anemones are rocking like foam-balls on a wreck-strewn sea ; and from the ditches, just the other day black, empty, and uninviting in the extreme, the marsh marigolds have raised their golden cups—their King-cups—to be filled with sunshine. We wished the birds farewell in Autumn as they passed overhead to lands that keep the sun, and now they are gathering around us again, and every swift's scream seems a promise, not a threat. Every lark in the meadow voices forth a promise. The butterflies seemed to fade away with the withering flowers, but their successors are flitting by. The shore-pools and the ponds seemed but a little while ago empty of life, or thickly frozen over —sullen at all events—but now, each is beginning to be like a busy city. For as surely as the old things pass away, so all things are made new. From what seemed a sealed tomb, life has arisen indeed.

But, if we can express the second Spring thought, it will be seen that there is a deeper sense in which these are the days of new things. It is, we see, the time of marrying, pairing, and mating.

> "For the old god Pan hath taken a wife,
> And the whole world shares their mirth.
> And all things that be of their company
> Are reft of rue and assoiled from strife
> By the one great breath of the joy of life
> That passes round the earth."

It is the time of giving birth to new lives. It is the time when new lives, begun long since, indeed begin to be. In all these young lives there is what is new; no one of them is quite like its parents, but each carries with it the promise

of better or worse; in the phrase of the biologists, this is the time of variations. It may be, indeed, that the newness is simply that what was of evil in the parents has been forgiven in their children, which is cause for rejoicing; but sometimes it is that the little child—be it human or water-baby—really leads the race, as was said long ago. It may be, of course—there's the rub—that the promise is never fulfilled, for the playful lamb which we all so much admire grows into a very stolid sheep, (man has such a way of making young things stupid); the very active-minded chick becomes a most matter-of-fact hen; the "promising" young anthropoid becomes a careworn, *abruti*, and rather cross-grained, elderly ape. Need we point the moral? The fact—at once hopeful and tragic—is that the young life is often ahead of its race. If the promise be fulfilled, then the world makes progress, and that is Spring.

But come, let us join in the mood of the season which is joyous. Let us mix all our metaphors, and let us light the Beltane fires (they are still always blazing at the proper time in some parts of the North), and let us keep the Floralia (they are still always kept in the South). For, while biology is well, to enjoy the realities which it tries to formulate is better; and, as was said by one who knew no fear of winter in his year—

> "To make this earth our hermitage
> A cheerful and a changeful page,
> God's bright and intricate device
> Of days and seasons doth suffice."

YOUNG THINGS

ONE of the dominant notes of Spring is youthfulness. It is the season of young things—of seedlings, buds, and young blossom, of tadpoles, nestlings, and young lambs. It is the time of new beginnings, of hopes and promises; in a word, it is the time when all the world is young. Let us consider some of the young things of Spring.

One of the fundamental but inconspicuous Spring phenomena is the multiplication of minute organisms in the waters. They swarm with water-babies. Sometimes the whole surface of the lake is green with minute plants, and we speak of "the breaking of the meres." The same is true of pond and river, of estuary and sea, though it must be remembered that in the great expanses of open sea—the pelagic realm—the conditions of life are much more uniform year in year out than in the shore waters or the lakes. Everywhere the multiplication of minute organisms is the necessary prelude to the general re-population. A single Infusorian may be the ancestor of a million by the end of a week; water-fleas eat the Infusorians, fishes eat the water-fleas, and so the basal multiplication influences a long sequence of incarnations. A little one becomes a thousand, and supplies a nutritive stimulus to a long chain.

Young gnats and mosquitoes are among the many very interesting "water-babies" to be found in stagnant freshwater pools in Spring. The mother insect, who has

spent the Winter in hiding, lays two or three hundred eggs on an early morning in Spring. She does so in such a way that they adhere to form a minute raft—about a quarter of an inch across—which floats on the surface of the pool, and can neither be submerged nor wetted. Each egg is somewhat cigar-shaped, with the upper end pointed, and the lower end with a lid, which opens to let the larva out into the water. The larva spends most of its time hanging head downwards from the surface-film, through which it protrudes a respiratory air-tube. Very delicate hair-like organs sweep microscopic particles into the mouth. If you push the larva below the surface it sinks to the bottom, but it can jerk itself up again tail foremost. There are no limbs, but the tail part can strike the water vigorously, and there are numerous tufts of bristles on the sides of the body.

The larva feeds and grows and moults, and after three or four moults it is full-grown—almost half an inch in length. It then passes into a pupa-stage, very markedly contrasted with the larva, and within the pupa-skin the transformation from larval to adult structure, which has been in progress for some time, is accomplished. The pupa has a strange shape, with a big "head-end" that seems all out of proportion, and with a paired paddle at the posterior end. It rests at the surface, head upwards, breathing by two horn-like or trumpet-like tubes. It does not eat at all, and when it is alarmed it has to swim forcibly downwards, so buoyant is its body. After three or four days of pupa-hood the cuticle splits along the back, the limbs are pulled out of their sheaths, and the gnat emerges, not without risk and difficulty. It rests for a short time, standing on its own husk, and then flies off into a very different world. The whole period of development is about a month, and there may be many successive

broods. Every one knows how fond the females are of blood; the males feed daintily on nectar, if they feed at all, and spend most of their short life in aerial dances.

One of the irresistible general impressions is that of the abundance of life, especially of minute life. As regards animals, this is seen most convincingly by those who study the sea, with its teeming surface population (the Plankton), or who fix their attention on some particular area, such as a shore-pool or a pond. It is an impression for a lifetime to go into a fish-hatchery and see the rows of rocking cradles in which the young fry are swarming, perhaps a hundred thousand in one box. But from many different sides we get the same impression—thousands of tadpoles in the ditch, countless swarms of grubs and caterpillars on land, clouds of mosquitoes rising from the marshes, hundreds of seedlings from one oak tree, an innumerable army of lemmings mustering in the valleys of the Tundra. Life is like an inexhaustible fountain—a spring.

A correlated impression is of the abundance of death. The mortality among the young is enormous. Out of a million oyster-embryos only one survives. Every one remembers Darwin's famous seed-plot in which so many lives began and so few grew up. Out of 533 larvæ of the large garden white butterfly collected by Professor Poulton, 422 died from ichneumon parasites; four out of every five—a great mortality. The infantile mortality in one of our British towns was 160 per thousand the other year. Everywhere we get the impression of a massacre of the innocents; " so careful of the type she seems; so careless of the single life."

Sometimes the thinning process takes strange forms, as in the capsules of the great whelk (*Buccinum undatum*), whose shell children hold to their ears that they may listen to the fancied echo of the distant sea, or in the vases of the

common dog-whelk (*Purpura lapillus*), which are fastened to the shelves among the rocks. The numerous eggs in each capsule or vase are not all hatched at the same time; some are a little earlier than the others, and the pioneers devour the laggards as they come on the scene—a curious instance of cannibalism in the cradle, an extreme form of the struggle for existence at the very threshold of life.

One of the biological certainties in regard to young things is their extraordinary plasticity, their power of acquiring modifications as the results of some peculiarity in nurture. By modifications we mean structural changes induced by peculiarities in surroundings or functioning. Every inheritance implies an appropriate environment of nutritive and other stimuli, apart from which the legacy cannot be realised. The inherited nature requires its appropriate nurture, and peculiarities in nurture—whether of food or sunshine, of use or disuse, of education or the lack of it—result in modifications. We must return to this very important subject, but meanwhile we note one of the general impressions of the Spring season, that young things are plastic, much in the grip of their surroundings, and very liable both for good and ill to put on veneer, to acquire modifications which are neither inherited nor transmissible.

The tricks that one can play with tadpoles, caterpillars, and other young things are endless; and the extraordinary modifiability of young children is one of the great facts of life. Every one knows and feels this in a general way; poets like Walt Whitman and Matthew Arnold have given it fine expression, but perhaps only the biologists quite realise the plasticity of the young life. It is, within limits, like clay in the potter's hands. This is *the other side of heredity*, so to speak.

Another general biological impression that we get from

watching many of these young things is that there is much truth in the frequently exaggerated idea of recapitulation. The conclusion that an animal climbs up its own genealogical tree is not to be taken literally, and Haeckel's more stately way of phrasing the idea, "Ontogeny tends to recapitulate Phylogeny," requires numerous reservations. The living creature is *specific,* itself and nothing else, from the very start, and it may show this in unexpected ways and very early in development ; but yet its early form and structure may in many cases be accurately described as old-fashioned and generalised. It is not till the sixth day that the chick within the egg begins to put on distinctively avian features, and it seems to us not inaccurate to say that during the previous five days it has been following a path precisely parallel to that along which a young crocodile travels. In a great number of cases, it is true, the young creature is a sort of nurse or vehicle of the definitive organism that is to be, and its salient features are adaptive to peculiarities of the larval life and not in the very least ancestral ; at the same time, when we inquire into the details of the organ-making (organogenesis) we often find that the successive developmental stages bear a striking correspondence to what we believe were the successive evolutionary steps. For these and other reasons—based on animal and human child-study—we adhere to a modified form of the much-abused recapitulation-doctrine, believing that the individual development of an organism tends to be a general recapitulation, often much condensed and telescoped, of the historical evolution of its race.

When we observe the growing of young things, whether they be seedlings or tadpoles, we have to reconcile two sets of facts—organic inertia on the one hand and organic divergence on the other. On the one hand, we see the persistent tendency to complete hereditary resemblance,

and the deep-laid arrangements, beautifully simple withal, for securing this. The child is as old as its parents, a chip of the old block, a pendant from a continuous chain of germ-cells. On the other hand, we see the expression of what is perhaps even more primitive—the tendency to vary, to be something new, to be creative. The living creature is a Proteus. In a deep sense, the little child leads the race. And there is no time when we realise this so much as in Spring, which, being the great season of birth, is also the season of making all things new.

THE TALE OF TADPOLES

THE frogs are among the earliest heralds of the Spring, for although their croaking (in March or earlier) may not be particularly attractive in our ears, it has the same deep *motif* as the nightingale's song. It is a " love "-call. Awakening after a winter's lethargy and fasting, the frogs creep out of the mud of the pond and call to one another. They unite in couples, and the eggs laid by the female in the water are fertilised by the male just as they are laid. These eggs form the familiar masses of " frog-spawn " that we see in the ditches and ponds—often, it must be allowed, in places which a little more intelligence would have avoided.

It is profitable to pause to take a good look at this frog-spawn, for it illustrates a number of biological ideas, and perhaps we may be fortunate enough to see with a pocket-lens the eggs dividing into two, four, eight, and more cells, as if they were being cut by an invisible knife. Each egg in our common British frog (*Rana temporaria*) is about a tenth of an inch in diameter; it is almost entirely black, all but a small white lower pole; it is surrounded by a large sphere of non-living jelly, corresponding to the white of egg in a hen's egg; and there is no egg-shell. The whole mass, often of 2000 eggs, sinks at first, but afterwards floats freely.

Let us consider the biological significance of these spheres of jelly around the eggs, for it is very interesting to notice how they are justified on count after count, though they are non-living extrinsic investments. The spheres

buoy up the eggs and at the same time obviate overcrowding. In the little chinks between the spheres there are often groups of green unicellular plants which liberate oxygen in the sunlight and use up the carbonic acid gas which the developing eggs produce—a most profitable association, a miniature illustration of the balance of Nature. But there is a fauna as well as a flora of frog-spawn, and the chinks are tenanted by small fry—such as water-fleas and rotifers—some of which eventually loosen the gelatinous envelopes, helping the larval-frogs to escape. Others, it must be admitted, seem to wait to devour. Once again, the envelopes of jelly are useful in lessening the risks of jostling—which might be fatal to the delicate embryos—when the wind raises waves in the pond, or when a water-hen or coot splashes in among the spawn. Moreover, the jelly seems to be unpalatable to most water animals, and it is so slippery that few birds can make anything of it. Finally, it may be that the clear spheres serve as so many greenhouses, enabling the ova to make the most of the sun's rays. All this illustrates the scientific view of Nature as an arena where efficiency in any form always counts.

About a fortnight or three weeks after the individual life began, that is, after fertilisation, the minute larvæ are hatched from the delicate envelope of the ovum, and begin to wriggle about in the dissolving jelly. They are somewhat awkward-looking, half-made creatures at first, and when they emerge from the jelly they are mouthless, limbless, eyeless, and gill-less. They attach themselves, often in long rows, to water-weed, the adhesion being effected by a paired cement-gland below the position of the future mouth. A bulging on the ventral surface of the body indicates the position of the still unused remains of the legacy of yolk.

Soon after hatching three pairs of external gills grow out, the first much the largest, one upon each of the first three

branchial arches. These are not comparable to the external gills of a young shark or skate, which are really elongated internal gills projecting through the gill-clefts. They are comparable to the true external gills seen in the young of some very archaic fishes, still living to-day, the *Polypterus* of the Gambia and some other African rivers, and two of the mud-fishes, *Protopterus* from Africa, and *Lepidosiren* from the Amazons. One or two days after hatching (in our common *Rana temporaria*) another important structure appears on the larva—the mouth is formed in the centre of a groove in front of the adhesive organs, and hundreds of small horny teeth are developed.

When the food-canal becomes open, four pairs of gill-clefts break out from the pharynx, and a gill-cover overlaps the first set of gills. These dwindle and are absorbed, their place being taken by a second set of gills supported by the hinder margin of the lower halves of four gill-arches. As these are enclosed in a gill-chamber and as they form a second set, it is natural to compare them to typical fish-gills. But they are really in the strict sense external, and they are certainly skin-covered. Each gill-chamber has at first its opening, but that of the right side joins with that of the left.

About a month after hatching the larval frog is in many ways fish-like : for instance, it has a two-chambered heart which drives impure blood to the gills, which are enclosed by a gill-cover. It swims by its laterally compressed tail, which shows a well developed unpaired fin, without fin-rays, however, which support the unpaired fins of fishes. *In a very general way* it may be said that the developing frog visibly climbs up its own genealogical tree. It is this general idea, indeed, of recapitulation that makes the study of the frog's life-history perennially interesting. It re-enacts the epoch-making colonisation of the dry land, and in many of its internal changes, *e.g.* in the making of the three-

chambered heart, it probably re-enacts what took place very long ago—before the Coal-Measures were laid down in Britain—when Amphibians evolved from a Piscine stock. But what took the race long ages to accomplish is achieved by the individual in a few days,—a fact so familiar that we are apt to forget its marvellousness—the mystery of cumulative and condensed inheritance.

With the acquisition of a mouth the larva begins to feed eagerly, nibbling at plants in the water, and also eating animal food. As a consequence it grows, and the food-canal, in particular, becomes very long and coiled like a watch-spring. It is interesting to notice the relatively great length of the intestine during the predominantly vegetarian period, for it is usual in the animal kingdom to find a diet of vegetable food—which is somewhat slowly digested—associated with length of food-canal or with some equivalent of length. As the tail becomes stronger and the power of locomotion increases, the horse-shoe shaped adhesive organ is converted into two small discs which gradually disappear.

A new stage is marked by the appearance of the hind-limbs as minute projecting buds at the boundary between trunk and tail. Why should hind-limbs appear earlier than the fore-limbs, which are, moreover, much shorter? Investigation shows that they begin to develop at the same time—a fact which gives additional point to the question. The fore-limbs are delayed by the gill-cover, which does not impede the hind-limbs, and they eventually emerge, the left one through the "spiracle," the right one by a rupture. Perhaps we get some insight into the orderliness of developmental processes when we notice that the microscopic lashes or cilia which have hitherto covered the skin of the larva now disappear. In most cases, except as regards reproduction, what we may call

"Animate Nature" (for shortness) is conspicuously *economical.*

After the appearance of the hind-legs, the larvæ come often to the surface to breathe. They are learning to use their lungs, which have been slowly developing for some time as pockets projecting into the body-cavity from the under side of the gullet. The tadpoles are now about two months old, and in having lungs as well as gills they may be compared to the double-breathing Mud-Fishes or Dipnoi. As the lungs become established and functional, the gills dwindle, and an intricate series of internal changes leads from an essentially fish-like heart and circulation to the characteristic Amphibian arrangements.

After a period of hearty feeding, with consequent increase in size and strength, the tadpole begins to show signs of approaching metamorphosis. It loses its appetite, it becomes much less energetic. The tail begins to break up internally, its muscles and other structures become disintegrated and dissolved, and most of the material is swept away in the blood stream to help in building up a better head. Wandering amœboid cells, which are present in almost all animals except threadworms and lancelets, seem to play an important part in the extraordinary process of absorbing the tail, working like sappers and miners among the débris, dissolving some of the material, carrying some away. In certain respects what occurs is comparable to violent inflammation. It is like a pathological process which has become normal, and thus from watching tadpoles we get a glimpse of a deep-reaching theory of disease as "a perturbation which contains no elements essentially different from those of health, but elements presented in a different and less useful order." Often, at least, a disease implies a series of metabolic changes which are not in themselves in any way extra-

ordinary—only they are out of place, out of time, and out of order.

One of the many careful observers of the annual wonder —the metamorphosis of the tadpole—gives the following terse statement of some of the more obvious changes: "The horny jaws are thrown off; the large frilled lips shrink up; the mouth loses its rounded suctorial form and becomes much wider; the tongue, previously small, increases considerably in size; the eyes, which as yet have been beneath the skin, become exposed."

As the tail shortens more and more, the tadpole, rapidly ceasing to be a tadpole, recovers its appetite and feeds greedily on animal matter, sometimes on its younger fellows. The abdomen shrinks, the stomach and liver enlarge, the intestine becomes relatively narrower and shorter. The tail is reduced to a short projecting stump, and, apart from this, the adult shape has been reached. Disinclination for a purely aquatic life becomes marked, and the young frogs clamber ashore. As they have lost all trace of gills, they are apt to drown in aquaria unless they have floating rafts to climb on to, or some other means of breathing dry air.

It is difficult to say which aspect of the development of tadpoles is most interesting. As we have seen, it is interesting in its main features as a modified recapitulation of that transition from aquatic to aerial respiration, from water to terra firma, which must have marked one of the most important epochs in the evolution of Vertebrates.

But it is equally interesting to go into minute detail and notice that the young tadpole's small tongue has not much muscularity about it; that as the tongue increases in size the muscles also increase, but yet are quite unable to move the tongue, though perhaps of some service in compressing glands; and that, as the metamorphosis is

accomplished and the frogling hops ashore, the muscles of the tongue are at length strong enough to shoot out the tongue on the day-dreaming fly. The peculiar interest of this is that Amphibians were the first animals to have a movable tongue, that of fishes being even worse than flabby, entirely non-muscular.

It is very interesting to consider in the same way the other momentous acquisitions made by the race of Amphibians—such as fingers and toes, and the power of gripping things, vocal cords, and the power of speech—though how much they have to say in their extraordinary jabber no one knows.

Another interesting consideration is the variety of solutions that this one animal, the frog, offers to the problems of its life. Even in mathematics, we believe, there may be more than one solution to a problem, and every one knows that this is true of the practical problems of human life. There is considerable variety in the solutions of the problems of *Brodwissenschaft*, though in strictness, we suppose, the fact of the matter is that the *conditions* of the typical problems are diverse, and therefore the solutions are diverse. But our point is this, that, to the two great problems of nutrition and respiration (if they are really *two*, for is not oxygen a kind of food?), the frog offers in the course of its life-history an unusual diversity of answer.

It will feed on its legacy of yolk, on unicellular Algæ, on the epidermis of aquatic plants, on the vegetable débris in the water, on animal matter by the way, on its own tail (of course in a sort of surreptitious phagocytic fashion), on its own brethren, on dead things in the water (tadpoles clean delicate skeletons beautifully), and, by and by, when it comes to its own, after a remarkable gustatory curriculum, it will feed on living insects and little else. Yet

the way it feeds as an adult, *e.g.* on beetles much too large for it, is often far from saying much for its varied gastronomic education.

And again, as regards the fundamental problem of breathing, we find the newly hatched tadpole breathing through its skin in the old-fashioned manner of earthworm and leech; then follow in succession, the first set of external gills, the gill-clefts, the second set of external gills, which are usually called internal; then follows a period with gills and lungs together; then there is the transition to terrestrial life with pulmonary and (retained) cutaneous respiration; finally, in winter, the hibernating frog, retiring into the mud-fortresses of its remote ancestors, breathes by its skin only.

Several experimenters have found that the numerical proportion of the sexes in frogs *appears as if it were* modifiable by changes in the nutrition. Thus Professor Yung, of Geneva, fed tadpoles with minced beef, and found that the percentage of females was 78, instead of 54 as in the control set in natural conditions. He fed another set with fish flesh, and the percentage rose to 81, as against 61 in the control set. In a third set, to which the flesh of frogs was supplied, the percentage rose from 56 to 92! It has to be noted, however, that subsequent experimenters have not confirmed these results, which are also open to the fatal objection that the sex of those tadpoles that died was not determined. It may have been that the change of diet affected the males prejudicially and favoured the survival of females. While the results of the experiments cannot, without further inquiry, bear the interpretation originally put upon them, they are still interesting, even if due to differential mortality. It is a well-known fact that in some places, in natural conditions, the percentage of females is very high, though 57 seems to be the average.

Before leaving the tadpoles, interesting in so many ways, let us think over the year's life of the frog. Throughout the winter months the frogs lie near the pond, buried in the mud, mouth shut, nose shut, eyes shut, with the heart beating feebly, breathing through their skin, and eating nothing. The awakening in Spring is followed immediately by pairing and egg-laying, and the aquatic juvenile life of the tadpoles occupies about three months. In summer there is a remarkable migration to the fields and meadows, and many hundreds of froglings, about the size of a first-finger nail, are seen on the march from the pond. The adults also migrate, and the meaning in both cases is the same—that they seek out places where insects abound. Of the many that go forth, only a remnant returns, for there is great mortality in the fields, where there are many physical risks and many alert enemies. The grass snake alone accounts for a good many in some parts of England. Those that escape—whether youngsters or old experienced hands—return to the pond in the autumn, and go into winter-quarters in the mud.

THE EEL-FARE

ONE of the sights of Spring is the "eel-fare," that is to say, the migration of young eels from the sea up the rivers. They are about 2½ in. in length, and like a very stout knitting-needle in girth. They come in countless crowds, and they keep on coming for hours sometimes—a seemingly endless procession, the head of one almost touching the tail of another, and all hugging the bank or at least avoiding the strong currents. Sunlight seems to be an indispensable stimulus to their persistent ascent of the stream, for when the sun went down behind the hills the procession we were watching suddenly stopped, the elvers had sunk into the mud or hidden beneath stones. The sunset is their rest signal. Their brain is wound up to go on—straight on—and wonderful feats are recorded in the way of swarming-up the sides of waterfalls and overcoming other obstacles. It has been said that those that are going to be females go much farther up-stream than those that are going to be males; but this lacks corroboration. It sounds rather like an *ex parte* assertion.

These migrating elvers have been well known to field-naturalists for many centuries, but it is only within recent years that we have been able to tell whence they come and whither they go. It seems that all the eels of North and West Europe come from deep water in the Atlantic to the west of the British Isles and France, and perhaps as far south as the Canaries — the apparent spawning-grounds

being on a belt running from north to south along the continental slope towards the eastern part of the Atlantic depths.

The "mystery of the eel" has engaged the attention of many naturalists, who have contributed to our present-day approximation to a solution. The biggest contributions are four. (*a*) In 1880, Jacoby proved that eels remained barren in fresh water, and suggested that the sexual maturity was not attained until they had gone far out into deep water. (*b*) About 1896, Grassi and Calandruccio concluded, from their observations in the Mediterranean, that the eel matures in deep water, where its eyes become larger; that it spawns in deep water, where its eggs float; that the development includes a metamorphosis, and that the larval form is the peculiar transparent pelagic creature which had been called *Leptocephalus brevirostris.* They found these in considerable numbers in the deep water of the Straits of Messina. (*c*) About 1906, Schmid found numerous specimens of this *Leptocephalus* along a belt from the Faroes southwards, described the metamorphosis into the "glass-eel" stage, and brought forward evidence of a migration shorewards during the process of change. (*d*) Another naturalist, Petersen, also deserves credit for showing that what had been called "silver" eels, with a silvery coat and big eyes, are the mature forms of the "yellow" eels of the ponds. They put on a "wedding garment" as they are about to go down to the sea.

As neither the first nor the final chapter in the life-history of the common eel is as yet known, neither the eggs nor the spawning adults having been discovered, one naturally asks for evidence in support of the statement that has been made as to their birthplace. The evidence, which we owe to the researches of Dr. Johs. Schmid, consists

in the discovery of places where the larvæ of the eel are actually the commonest fishes towards the surface. Arguing by analogy from the case of other fishes where great swarms of larvæ occur near known spawning grounds, Dr. Schmid infers that the birthplace of the eels must lie along the belt of the abundant occurrence of larvæ.

Though absolute certainty is awanting, there is good reason to believe that the eggs are "bathypelagic," that is to say, that they occur floating at considerable depths. This is true of some other members of the eel family, of argentines, and of other deep-sea fishes, and it must be contrasted with cases like the herring, where the eggs are *dimersal* (*i.e.* attached to the bottom), and cases like most of our food-fishes, where the eggs are *pelagic* (*i.e.* floating at or near the surface of the open sea).

It is *probable* that the eggs of eels are hatched in complete or almost complete darkness, at a depth of at least 1000 metres, where there is a pressure of about 100 atmospheres and a temperature of over 70° C. Nothing is actually known of the first chapters in the development—the forming of the body, the early nutrition—all is still in darkness till we reach the stage known as the *Leptocephalus*.

For a long time naturalists have known of a thin, transparent open-sea creature—which was called *Leptocephalus*, and regarded as a peculiar kind of fish. By careful observations along various lines it has more recently been shown that the Leptocephali—for there are several different species—are stages in the life-history of eels. We shall only mention two contributions. In 1864, the American naturalist, Dr. Theodore Gill, now a veteran in the ranks of ichthyologists, concluded on anatomical grounds that *Leptocephalus morisii* was the larva of the conger-eel. In the summer months of 1886, at the marine laboratory of Roscoff, in Brittany, Professor Yves Delage observed

the gradual transformation of a *Leptocephalus* into a young conger.

Let us linger for a little over the Leptocephali. They are about 3 in. long, almost as thin as knife-blades, and as clear as glass, except that the iris of the eye is silvery. In this transparency they resemble many of the open-sea animals—"sea-butterflies," "salps," and the like—with which they consort, and it may be that the character is of protective value, for they are almost invisible in the water. They are found in greatest abundance at a depth of about fifty fathoms, but are often got close to the surface. They seem to have a diurnal change in their level in the sea, coming nearer the surface at night. They are said to swim with beautiful undulating movements, more leisurely than rapid, and they often remain quite still—at rest in the water. So far as is understood, they do not feed and therefore do not grow. They may be spoken of as the second great chapter in the life-history of the eel.

At this point it may be explained that besides *Leptocephalus brevirostris*, which is the larva of the common eel, there are two other kinds of Leptocephali, which are the larva of the conger-eel and of the deep-sea eel, and four other kinds which have not yet been linked to their respective adults. One of them, called *Leptocephalus hyoproroïdes*, is of particular interest, because it is as yet the only form in which it has been possible to trace back the *Leptocephalus* stage to an earlier, not fully grown, *pre-Leptocephalus* stage. In other words, the end of Chapter I. is in this case known, and connected with Chapter II. It is noteworthy that the *pre-Leptocephalus* is also pelagic.

To return to the life-history. In the late autumn, so the story goes, the knife-blade-like larvæ of the eel begin to undergo a slow metamorphosis, as the outcome of which

they assume in miniature the semblance of their parents. In the first period of change, the *height* of the body is reduced so that a form of body results that is in the main eel-shaped. Thus, out in the Atlantic, "glass-eels" or "transparent elvers," are fashioned. "In contrast to the earlier flat *Leptocephalus* stages these are now strong and swift as arrows in their movements." During the second part of the metamorphosis the *length* of the body is reduced, and the elvers migrate, pressing in from the open sea to the fresh water or the shallow coastal waters, where they can complete their metamorphosis and begin again to feed and grow. For the whole of the change is a fasting period, as is so often the case in developmental transformations—a biological justification of asceticism. And it lasts about a year!

The remarkable diminution in length, which occurs in the metamorphosis from the *Leptocephalus* to the "glass eel" stage, amounts to 1 centimetre, and careful weighings of the two stages have shown that the metamorphosis involves an actual loss of substance, the dry-weight of the "glass-eels" being only one-third of that of the Leptocephali. That means, of course, that during the fasting period of eight or nine months there is a literal consumption of a considerable part of the material of the body.

These results of the careful work of Dr. Schmid and his colleagues can be readily enough summed up, but it is of some importance to understand that the provisional story of the life-cycle has been built up of numerous observations—which were not very striking by themselves. Thus we read that the captures in May were all Leptocephali, while those in September were mostly in process of metamorphosis; that the later stages in September were nearer shore than the earlier stages, which points to shoreward migration during metamorphosis; and so on.

The area on the continental slope away to the west of the English Channel is regarded as the most northerly of the main spawning places of the eel in the Atlantic, and it is very interesting to notice that the recorded dates of eel-fares in the various British rivers correspond approximately to the distances from the main spawning ground. To give a few illustrations, "the elvers first appear at Spain and far south at the French west coast (at Bayonne), namely, in the last months of the year (October to December), somewhat later farther north on the French west coast in January, still more to the north in February, and in the Channel in February to March. In South-West England (Bristol Channel) the fishery also begins in February, or rather in March." On the Danish North Sea coast the ascent of the elvers begins in April or May, on Scottish rivers, like the Tay and the Dee, it usually begins in May. This is, of course, but a sample of the evidence that has accumulated to show that the date of the eel-fare corresponds, on the whole, with the distance the young eels have had to swim from their spawning place. They are ready to start about November, but they do not reach the Kattegat till May—after a long journey. The discovery of the spawning grounds has also explained why such colossal numbers of elvers are sometimes seen in the Severn—the arms of the Bristol Channel form a huge trap for a large contingent of the main migratory host.

What happens in the case of the common eel seems to be paralleled in the case of the conger. It is a more southern form, and its larvæ do not come farther north than Rockall. The Leptocephali do not occur over such great depths as those of the eel, but there is the same sort of metamorphosis and the same sort of shoreward migration. But the conger remains in the sea.

As we began by noting, the elvers pass up the rivers

in huge numbers, overcoming difficulties that seem at first sight insuperable. They often "swarm" up the sides of falls; they may get up drain-pipes into ponds; they not infrequently make excursions into the damp grass of meadowland. Perhaps no animal exhausts the possibilities of habitat so thoroughly as the eel—it has experience of the deep sea, the open sea, the shore, the river, the pond, and even the solid earth!

They may remain in ponds for many years, growing steadily larger year after year, for, like many other fishes, they have no definite limit of growth. There is a record of an eel that was kept in captivity "for upwards of forty years, growing to a length of 4½ ft., being already of large size at the time of its capture." But, however long they may live and thrive in fresh water, they do not breed there.

Two or three rare cases are known of female eels taken from fresh water which had well developed ovaries or roes, but no evidence of spawning has ever been forthcoming. Furthermore, the eels which are caught going down the rivers to the sea in autumn are *not* in a ripe condition, though it is probable that they very soon become so under the stimulus of their old environment.

In the ordinary course of events, the females become almost mature "silver" eels in seven or eight years (7–12 years); we have seen big individuals, approaching a yard in length, descending the Dee at Aberdeen. The males put on "silver" at an earlier age, usually about four and a half years (four and a half to seven), and they are several inches smaller than the females. The maximum dimensions are 19 in. and 39 in. respectively.

The fact is, then, that as the eels approach maturity they become restless and seek the sea, if they may attain unto it. For, in some cases, the pond which was with difficulty reached by an elver, is not more easily left by

an eel. An overland excursion is sometimes required, oi a drain-pipe may serve. In passing from the rivers to the sea the males are said to lead the way in some cases, as statistics of capture seem to bear out. They go down to the depths of the sea, from which there is certainly no return. But whether they die after spawning, as is probable enough, no one knows with certainty.

A life-history so weird and circuitous as that of the eel raises many questions, and the need of some general interpretation is obvious. To some extent that is supplied by the theory to which many facts point, that the common eel is originally a deep-water fish which has secondarily taken to fresh waters, just as the salmon is a freshwater fish which has secondarily taken to feeding in the sea.

Part of the argument is based on the fact that animals usually go back to their original home to spawn. The toad is in the main a terrestrial animal, but it spawns in the water. The land-crab often lives far from the sea, but it journeys to the shore at the spawning season.

Again, from the fact that most members of the eel family (Anguillidæ) are marine fishes and only a few enter fresh water, we may infer that the habitat of the exceptional minority is secondary. It is, furthermore, very significant that, out of a total of about 150 species, about fifty are found in the Deep Sea in the stricter sense, going down to 2500 fathoms.

The deep-sea eel (*Synaphobranchus pinnatus*) of the North-East Atlantic keeps to the abyssal habitat, which was probably primitive for the common eel. Its larvæ have never been taken so near the surface as the Leptocephali of the common eel, never, indeed, above about 50 fathoms. There is nothing to suggest a movement towards the shore. On the contrary, the larvæ sink during metamorphosis towards the floor of the sea, where they become mature.

To speak of the common eel as originally a deep-sea fish requires, perhaps, the safeguarding statement, that there is no reason to believe in the autochthonous abyssal origin of eels. Before the eels colonised the great depths they were probably littoral fishes, specialised for burrowing in the mud, and for making their way through holes among the stones. Perhaps this hypothetical, even more remote, habitat has its organic reminiscence in the shoreward migration of the glass-eels.

To the question why eels which have reached reproductive age in rivers flowing into the North Sea, for instance, should travel far out into the Atlantic to spawn, it may be answered that most parts of the North Sea are too shallow, and where the depths are sufficient the temperature is too low.

Let us revise the general sweep of the life-history of this remarkable deep-water fish which has left the abysses and has entered into intimate practical relations with man. It probably begins its life below the 500-fathom line on the verge of the Deep Sea in the stricter sense—that dark, cold, calm, silent, plantless world. It develops and starts in life, and feeds and grows, far below the surface. It rises to the upper waters as a transparent, sideways flattened, knife-blade-like larva. It is gradually transformed into a glass-eel with an energetic disposition, and after about a year it is one of a million elvers passing up a river. If it is not fortunate, it may take much more than a year to reach the feeling-ground, for which it has doubtless some organic, *deeply sub-conscious* desire; those that ascend the rivers flowing into the Eastern Baltic have journeyed over 3000 miles. Eventually they pass up the streams, and there is a long period of growth in slow-flowing reaches and in fish-stocked ponds. There is never any breeding in fresh water; but after some

years restlessness seizes the adults as it seized the larvæ—but a restlessness due to a reproductive, not a nutritive, motive—and there is an excited return journey to the sea—the verge of the deep sea—where, as far as we know, the individual life ends in giving origin to new lives.

CATERPILLARS

THE sight of the first butterflies is always gladdening, even when they are the mischievous cabbage whites (*Pieris*). For it is an indication that summer is setting in. Most of these early butterflies have spent the winter in the pupa-state, hidden away in sheltered retreats. They emerge and pair ; the females lay their eggs ; these develop into the caterpillars which are often so abundant in the summer months. As we have studied young creatures in the sea and in the fresh waters, we may take caterpillars as examples of young creatures on dry land.

A typical caterpillar—the larva of a butterfly or a moth—shows a hard polished head and a body of thirteen rings. The head is strengthened by a median shield and two side-plates bearing half a dozen simple eyes and minute three-jointed feelers — in marked contrast to the large compound eyes and long feelers of the adults. In the service of the mouth there are three pairs of minute appendages—the mandibles and two pairs of maxillæ. On the second pair of maxillæ, fused to form the labium, there is in many cases a spinneret from which a thread of silk issues. In not a few caterpillars there are also mandibular glands secreting a fluid which is usually defensive, occasionally digestive as well. Associated with the silk-glands, the old entomologist Lyonnet found accessory glands, whose secretion seems to glue one thread of silk to another and perhaps helps the silk to harden quickly. Each thread of silk shows a glassy core of pure silk, made at the expense of the living matter

of the cells of the silk-glands, and outside the silk there is a delicate fatty sheath which can be removed by washing. The caterpillars use the silk to attach themselves to twigs, to save themselves when they are about to fall, to lower themselves from a branch to the ground, and to make a cocoon for the period of metamorphosis. But there are many caterpillars that are not silk-spinners.

Returning to the structure of the caterpillar, we see that the first three rings behind the head bear five-jointed legs ending in a point. This region corresponds to the thorax of the full-grown butterfly or moth, and though the legs of the larva do not in the strict sense become those of the adult, they correspond to them. Behind the thorax, and quite continuous with it, is the abdomen, which consists of ten segments. In most cases, however, the ninth is telescoped and difficult to see. Short unjointed legs, ending in peculiar gripping structures with a double crown of hooks, occur on the third, fourth, fifth, and sixth rings of the abdomen, and a large pair (sometimes transformed into protrusible whips) is borne on the tenth and last. There are, of course, occasional departures from the rule that there are five pairs of pro-legs. Thus in the "loopers," which move in a characteristic way, familiar in the common magpie moth (*Abraxas grossulariata*), there are only two pairs.

There are paired breathing apertures, leading into air-tubes or tracheæ, on the first thoracic ring, and on the eight foremost abdominal rings. Not infrequently the body is thickly covered with hairs which have irritant properties; or instead of hairs there may be bristles, spines, or warts. Some caterpillars have offensive thoracic glands; thus those of the puss-moth larva secrete formic acid. Inside the body there are, of course, organs corresponding to those that we possess — brain and nerve-cord, food-canal and associated glands, complex muscles, air-tubes, a heart, excretory tubes,

and large fatty bodies. It is not within our purpose to discuss any of these things, but it is necessary to recognise that the caterpillar is a very highly organised creature.

Most caterpillars lead an active life, moving about in search of food. Some rove by day and others by night. In some dim way they are aware of the appropriate food-plants, passing others by, and certain kinds may often be seen exploring in a most business-like fashion. The procession caterpillars of the genus *Cnethocampa*, which rest together in a huge common web, go on the march in large numbers, sometimes in single file, sometimes in broad ranks. In the Italian Riviera one of the procession caterpillars (*Cnethocampa pityocampa*) makes a great silken shelter on the branches of the Aleppo Pine, and often eats them quite bare, doing great damage. They are checked a little by the larva of a beautiful beetle (*Calosoma*) which "forces its way into the silken nest and destroys the inmates. So voracious is this grub that it kills many more of the caterpillars than it can possibly eat. It is wisely protected by those who are interested in the preservation of the pine forests." These procession larvæ may be seen on the march about the date of the vernal equinox, forming long lines on the road, the head of one almost touching the tail of another. As they go they sometimes secrete a composite thread, continuous to their headquarters on the tree. It has been shown experimentally that they instinctively follow the leader, and that he may abdicate his position in favour of another. The experiment has been tried of making a circle of the procession, the head of the leader being brought into contact with the hind end of the last on the file, and such a circle has been known to go on circling for days—a fine illustration of the non-intelligence of instinct.

The biological significance of the procession is that the caterpillars are seeking for a suitable soft place in which to

bury themselves for pupation. When they find it, they mass together, and move round and round paying out silk and loosening the soft soil. In this way they gradually sink below the ground, where they lie dormant, undergoing metamorphosis through the summer. The moths emerge in autumn.

These destructive caterpillars are familiar sights in some parts of the Riviera, and they have many interesting features in addition to their processions. Thus the loosely attached hairs, which are covered with fine recurved hooklets, are very irritant to many people (and not at all to others), causing a rash on the skin when the caterpillars are handled.

Mr. W. F. Kirby writes: "The hairs of the processionary larvæ, which are very loosely attached and studded with exceedingly fine and recurved hooks, cause violent inflammation on the skin of men and animals, partly by thus adhering to it, and partly in consequence of a fine dust with which they are covered. On this account the neighbourhood of the nests of these larvæ, which are intermingled with these hairs, is dangerous, for the surrounding air is filled with loose hairs and dust, which are liable to be inhaled, and to give rise to internal inflammation and swellings, which have sometimes caused death. The inflammation caused by the hairs of the larvæ may be relieved or averted by rubbing the skin with oil."

Another feature in the life of caterpillars is their enormous appetite. Some of them seem never to stop eating, and a species of *Polyphemus* is said to eat 86,000 times its own weight in a day. The contrast between this and the dainty meals of the butterfly or its not infrequent fasting is almost diagrammatic—the larva is the nutritive, vegetative, growing phase; the adult is ascetic and reproductive. In the great majority of cases caterpillars are vegetarian,

and it seems that they can digest only the fluid parts of their food, which sheds some light on the enormous quantity eaten.

The extraordinary voracity of caterpillars is associated with rapid growth, and this with periodic "moulting." As in the other jointed-footed or arthropod animals (such as centipedes, spiders, and crustaceans), the body is covered with a chitinous cuticle—a layer not in itself living or cellular, made by the underlying living skin. It is really of the nature of a secreted shell; it cannot grow, and it has little expansibility. Therefore, as the caterpillar grows, it is continually becoming too large for its protective cuticle, and that has to be moulted. Five moults very frequently occur. Every moult is extraordinarily thorough-going, involving all the many intuckings of the outer layer, and the caterpillar is emphatically out of sorts at every moult. There seem to be serious respiratory difficulties, and there is considerable inflammation. The moult is a critical event in the life-history, and the process often ends fatally.

After the caterpillar has reached its normal limit of growth it passes, as every one knows, into a resting phase, which is often prolonged for many months. It becomes a pupa, nymph, or chrysalis, and undergoes metamorphosis. In many butterflies and some small moths, the larva fastens itself by its tail to a twig; in many other cases it suspends itself by a silken thread; some hide between two leaves fastened together by silk; many burrow beneath the ground; most moths make some sort of cocoon or shelter, which may be of pure silk neatly wound, or of silk mixed with hair and all manner of external things—such as pieces of leaf, bark, moss, and lichen, and even grains of earth. These cocoons are usually constructed in sheltered corners, and are often very

inconspicuous. The finest pupa-cases are surely those which are spun of silk (in most moths), and the making of them in a few days is an extraordinary instance of the intensity of chemical processes in the body, and also of great muscular activity on the part of a creature that is about to fall into sleep. The long thread of silk is a secretion, that is to say, it is a not-living organic substance manufactured at the expense of the living matter of the cells composing the silk-glands. It is spun into a cocoon by persistent movements of the head, which must imply great exertion; thus the larva of *Polyphemus* is said to move its head a quarter of a million times in making its cocoon.

Within the pupa cuticle a remarkable process occurs, which has excited the wonder of many generations of naturalists, and is still imperfectly understood. The body of the larva is broken down and is built up again on a new architectural plan. Clusters of active embryonic cells become the foci of new formation, and wandering amœboid phagocytes, working like sappers and miners among the tissues, transport material from place to place. Although the breaking-down (or histolysis) which precedes the reconstruction (or histogenesis) is never so thoroughgoing as in flies, where the pupa returns almost to an egg-like state, there is a gradual transformation of almost all the organs. One may compare what occurs to a not unfamiliar sight, the piece-meal pulling down of a large building, such as a railway station, and its *pari passu* reconstruction, but all so regulated that the essential activity—and what else is *life*?—does not come to a standstill.

When the reconstruction is completed—which may take a couple of weeks or as many years—the fully formed insect or imago emerges from the pupa-case—its last moult. It is often rather soft and flabby on its emergence,

but it soon hardens up and there is no more growing. Many of the details of the liberation of the butterfly or moth are extremely interesting, thus there are often lids which open neatly ; there is sometimes a transitory head-organ that helps the escape, just like the "egg-tooth" with which young birds break through the egg-shell ; the puss-moth secretes caustic potash from its mouth which dissolves away the pupa-case.

The ranks of the caterpillars are thinned by the weather, by many birds, and by other harassing enemies, such as the Ichneumon flies which lay their eggs in the juicy body. The risks that caterpillars run are so many that their survival is sometimes surprising. In the main it is secured in two ways—by sheer force of numbers on the one hand, and by numerous protective adaptations on the other. The importance of the latter, which are often very subtle, will be better realised when we remember, what Alfred Russel Wallace pointed out, that it is essential for most caterpillars to escape even a tentative peck. The soft-walled tense character of the body is "extremely dangerous, for a slight wound entails great loss of blood, while a moderate injury must prove fatal."

The protective adaptations are manifold. Hairy caterpillars are left alone by most birds, though the cuckoo seems to relish them. Not a few secrete offensive fluids, such as formic acid, when they are touched. Some have an unpleasant smell, and others are unpalatable, as experiment has shown. Some hide during the day, others play 'possum when touched. Some lash with their tail whips and strike "terrifying attitudes." But the subtler line of adaptation is that seen in the numerous instances of protective resemblance. Thus some caterpillars are extraordinarily like stunted twigs or little knobs on a stem ; others are like little splinters of wood or the curled margins of withered

leaves; many show a detailed and exact resemblance to some part of the plant on which they feed. Sometimes, moreover, the colour-resemblance is variable, being adapted to a number of food-plants. M'Lachlan noted, for instance, that the larvæ of *Eupithecia absynthiata* were yellowish on the yellow ragwort (*Senecio jacobœa*), reddish on the purple centaury (*Centaurea nigra*), and white on the white and yellow mayweed (*Matricaria*).

A fine illustration of the actual life-saving value of the protective coloration is given by Professor Poulton and Miss Sanders. They fastened 600 pupæ of the tortoise-shell butterfly (*Vanessa urticæ*) to nettles, tree trunks, fences, walls, and so on. At Oxford there was a mortality of 93 per cent., pointing to an extremely high elimination rate, and the only pupæ that survived were on nettles, where they were least conspicuous. At St. Helens, in the Isle of Wight, the elimination was 92 per cent. on fences where the pupæ were conspicuous, as against 57 per cent. among nettles where they were inconspicuous. This is a kind of evidence that is much needed—definite proof of *discriminate elimination* in the struggle for existence.

It is probable that the stock from which insects evolved had its roots among the segmented worms. Part of the argument for this conclusion is to be found in a class of very interesting connecting links, known as Onychophora—old-fashioned types with many resemblances to Annelid worms on the one hand, to centipedes and insects on the other, and widely represented in different parts of the world by several genera, of which the best known is *Peripatus*. There are also some very primitive relatives of the familiar centipedes and millipedes, certain of which come very near the primitive wingless insects. So that, while one must admit that the characters of caterpillars are in details adaptive to the prolonged vegetarian larval period, it

may be that some broad features, such as the worm-like shape and the numerous limbs, are recapitulative of ancestral characters.

The life-histories of butterfly and moth, which we have briefly illustrated, exhibit in a very striking way the deep-rooted organic tendency to alternations of activity and passivity. The developing egg lies still, its activity is all in its internal formative processes, it subsists on its legacy of yolk, and it is enclosed in a shell often beautifully sculptured. Out of the egg there emerges an active, roving larva with a huge appetite and rapid growth. This passes into a state of quiescence; the pupa is more or less isolated from the outer world and often very securely encapsuled; it lives upon the stores accumulated by the larva. But out of the passive pupa there emerges the winged insect, an intensely active creature in its more typical forms, a Psyche that has freed itself from earth and lives for love. This strangely zigzag life-history may be condensed into the space of a year, the hibernating pupæ becoming winged adults in spring or early summer, or, it may be, punctuated in other ways and drawn out over several years, as in the case of the goat-moth. But of all the marvels of the life-history the central one is the greatest —that remarkable disruption and reconstruction by which the caterpillar is changed into the winged insect.

RHYTHMS IN PLANT LIFE

EVERY one recognises that, in a general way, Summer is a season of great activity among plants, and Winter a season of rest. This is one of the broad expressions of the fact that all life is rhythmic. Professor Pfeffer, one of the highest authorities on the physiology of plants, has summed up the situation in one of his terse paragraphs:[1] "All life is rhythmic in character, each life-cycle being a repetition of a preceding one, and during the progress of the grand period of each individual, various periodic movements occur in growing and adult organs. Further, all metabolism consists of rhythmically recurrent processes of anabolism and katabolism. In addition to this autogenic rhythm, regularly repeated external factors may induce a secondary or aitiogenic rhythm, and the phenomena observed in nature are the result of the co-operation of these two forms of rhythm."

Some of the clearest examples of periodicity are found in the alternations of vegetative and reproductive periods, and it has been shown in a variety of cases, especially among Algæ and Fungi, that reproduction is induced by appropriate changes in the external conditions. It can be hurried on, or kept back, or suppressed for prolonged periods. The beautiful experiments of Klebs on Algæ, such as *Vaucheria*, *Spirogyra*, and *Hydrodictyon*, show that the external conditions punctuate the life-processes, determining whether

[1] *The Physiology of Plants*, vol. ii. Trans. by Ewart, Oxford, 1903, p. 197.

there shall be a period of vegetative growth, or asexual reproduction, or sexual reproduction. As Pfeffer says: "In Algæ, the stimulation is usually due to such factors as light, water, or temperature, and a regular alternation of generations would be maintained by a constant periodicity of the climatic factors." In the higher plants, as in the higher animals, there seems to be a relatively greater freedom from the direct grip of the environment, and the altered conditions which bring about flowering, for instance, may be of internal origin, that is to say, not in *direct* dependence on the march of the seasons or any other external periodicity. Keeping in mind this general idea of internal rhythm and external punctuation, let us think of some of the fundamental facts of plant life in spring.

Germination

Increasing warmth, more light, softer winds, and Spring showers—these are some of the familiar physical conditions of the universal reawakening in Spring. Were we wise enough we should be able to trace the whole chain of causes—the long succession of stimuli—which connects the increased share of the sun's energy with the germination of seeds, the ascent of sap, the unpacking of buds, the return of the migrants, the rise of song in the bird's throat, the awakening of the sleepers, the emergence of the butterfly from the chrysalis, the quickening of the pulse in man. "Our very hearts have caught the charm that sheds a beauty over earth."

Let us first think for a little of the germination of seeds. Among plants, as among animals, one of the lines of evolution which is discernible is that which leads to prolonged connection between the mother organism and its offspring. In a seaweed, for instance, what leaves the parent organism

is usually a single cell, but it is an acorn—a formed young thing—which falls from the oak tree. The salmon spawns on the gravelly bed of the river, but to the mammalian mother a child is born. There is progress not merely to viviparity, but to bringing forth an offspring at a more and more advanced stage. The embryonic period tends to swallow up the larval period. The advantage is plain, for, other things being equal, the less weak and helpless an organism is when it leaves its parent, the greater are its chances of surviving. Robert Chambers, the author of the *Vestiges of Creation*, made much of this sound and simple idea. There is prodigious infantile mortality among many of the lower animals—especially among those which have no parental care either conscious or unconscious. We need only recall that the conger-eel is said to have about ten millions of eggs. Part of the object of fish-hatcheries is to shelter the developing embryos and larvæ until they are able to do a little in the way of fending for themselves. It has been suggested that one of the reasons why the giant reptiles disappeared from off the face of the earth was that their eggs were persistently devoured by egg-eating birds and mammals.

The seeds which are so numerous in the ground—so numerous that Darwin reared eighty seedlings from a single clodlet on a bird's foot—represent an enormous store of potential energy. They have a long history behind them. "Formed in the warmth and brightness of last summer's sun, ripened in the glow of Autumn, they fell to the ground, were carried hither and thither by trickling runlets of water, by the winds, by animals, and scattered over new pastures. Through the long chill of winter they remained asleep; but not dead—slow preparation was being made for the new day."[1]

While a few seeds, such as those of poplars, must germinate at once (*i.e.* in a few weeks) if they are to develop at

[1] *Study of Animal Life*, p. 127.

all, this is not the way with the majority. For most there is a period of quiescence—which for some may be experimentally shown to be imperative. That it is not purely adaptive to the inhospitable state of the earth and the cold weather, is proved by the fact that some seeds will not germinate at once even in propitious conditions, and that others wait over several years. This may be interpreted partly as an alternation of rest after activity—just as the embryo hydra develops for a while and then rests for six weeks; partly as a consequence of the firm protective husks and of the relatively enormous quantity of capital or reserve products with which, like a development-inhibiting legacy, so many seeds are weighted; and partly as adaptive to the seasons.

The analogy between dormant seeds and dormant eggs is far-reaching, and may be followed into details. Thus it seems to be a necessary condition for the development of some animals, such as the Phyllopod Crustaceans Apus and Branchipus, that the ova should be subjected for a period to desiccation. In many cases one of the conditions of the survival of the animal egg is the possession of a firm protective shell, which is obviously comparable to the husk of the seed, just as the yolk is to the seed's albumin.

Noting as the main physical conditions—warmth and moisture—we recognise as the chief facts in germination:—

(1) The insoaking of water, often through a specially porous area, such as the brown mark or hilum at the base of the bean;

(2) The reawakening of the protoplasm (and we must remember how peculiarly thirsty for water plant-protoplasm is);

(3) A fermenting process by which the hard stores in the seed are rendered soluble and diffusible by a process comparable to animal digestion; and

(4) The interesting way in which Bacteria—the minions

of Death—help to loosen the bonds of birth—rotting away the hard husks.

The fermentation which goes on in seeds and seedlings, making hard reserve material available for transport and transformation, brings home to us the fundamental unity of vital processes. There is a close resemblance between digestive fermentations in animals, which make the solid food diffusible, and the fermentations in plants. The list of chemical substances known to be common to plants and animals is enormous, and it includes a number of digestive ferments.

Thus the diastase which Professor Vines and others have proved to be present in every green leaf is *comparable* to the ptyalin in our salivary secretion. Both change starch into sugar. A diastatic ferment certainly occurs in many seeds, bringing about the same change, and various observers have found a peptic ferment like that in our stomachs, turning proteids into peptones. And Professor J. Reynolds Green found a ferment like that of the animal pancreas in the seeds of the Lupin.

There is, however, great discrepancy among chemical physiologists in regard to these peptic ferments in seeds, and we cannot enter into the very difficult questions involved. Suffice it to say that there is often much stored proteid in seeds—more than there is for a time in the young plant. In some way this condensed reserve material is made available. There is no doubt that seedlings have a peptic ferment which acts in the presence of an organic acid, but its presence remains doubtful in many seeds where some sort of digestion must go on. Perhaps the protoplasm of the seed sometimes does its own fermenting of reserve material, without the aid of any specialised ferment.

The rapidity of growth that follows germination in a

good season is sometimes almost magical. Kropotkin tells us that around Tobolsk the sown fields are harvest fields in about two months; and Brehm has given us a graphic picture of the coming of the Siberian spring, which shows a greater abruptness than in our latitude. In a few days the desert is as the rose, the barren grounds of the Tundra become a garden, the Steppes are covered with lilies, and the silent hills shout for joy. All of which would be impossible were it not that in seed and bud, in rhizome and corm, there is an enormous storehouse of treasure waiting as it were for a word, the "Open Sesame" of sun and shower.

But the legacy of the young plants is soon exhausted, and they begin to fend for themselves. At this transition there is sometimes a slight hiatus, which may be compared to weaning, or perhaps more accurately, to the loss of weight that occurs in mammalian offspring for a few days after birth. The well-known "swooning" or waning growth of the young corn at a certain stage corresponds to the exhaustion of the seed-store and to the beginning of entirely independent nutrition. This leads us naturally to think of another feature of plant-life in Spring—the uprush of sap.

Ascent of Sap

No fact of plant life is more important than this ascent of sap, but we are far from a complete understanding of it. The facts are that water, bearing mineral salts in solution, passes from the soil into the roots by physical osmosis modified to some extent by the facts that the cells of the root are living. The inward flow is greatest in Spring and least in Winter; its rapidity and pressure vary within wide limits.

The upward path is by the cells and vessels of the young wood, as may be proved in a variety of ways. That it is

not by the bark is proved by the fact that the leaves of a tree from which a ring of bark has been removed are still able to flourish. That the path is not by the central wood is plainly shown by the fact that a tree whose heart has rotted out may still bear fresh and vigorous leaves. Thus we may at once assert that the upward path of the sap is by the outer or younger wood.

As to the use of the ascending current, the answer is complex. It forms the whole food-supply of the plant except the gases absorbed by the leaves from the air. The water enters into the formation of starch and proteids, and the salts also help more or less directly. The water also serves to maintain the vigour of the protoplasm, for abundance of water is almost always a condition of activity in plant cells. Finally, no small part of the water makes good the loss which leaves are always suffering from radiation.

The factors are (1) the difference of density between root cells and soil water; (2) the suction from the leaves which obviates the dilution of the whole plant; (3) the action of capillary forces; and (4) the special activity of certain cells on the upward path.

Unpacking of Buds

Comparable in many ways to the germination of seeds is the unpacking of buds, which is equally characteristic of the Spring. Like the seeds, the buds were made in the abundance of a past summer; they express the superabundance of vegetative life. Like the seeds, the buds are adapted to contain much within small compass, and are protected by scales which correspond to husks. Like the seeds, the buds have a period of quiescence after the period of formation, for many of them remain nine months or so in a dormant state.

Of interest is the neat way in which the young leaves are packed within the bud, being usually twisted in a spiral, corresponding to the spiral which the leaves eventually exhibit when they are unfolded and outspread upon the shoot or branch.

The prime conditions of the unpacking of buds are, of course, to be found in the Spring sunshine and the Spring rain. Under the influence of increasing warmth the water from the soil ascends to the sleeping buds and recalls the cells to activity. These swell, become active, and multiply, and the pressure from within bursts the scales outside, which in dying away have saved the tender life within.

Multiplication

One of the fundamental and far-reaching facts about the life of plants in Spring is much less familiar than the germination of seeds, the rise of the sap, and the opening of buds. It is the extraordinarily rapid multiplication of minute water-plants—of unicellular Algæ in particular. The importance of this lies in the provision of an almost exhaustless food-supply for water animals. The complex organic substances which the plants build up, with the sun's aid, from air, water, and salts in solution, become part and parcel of one animal after another through long series of reincarnations. As to the rapidity with which a pond or a lake becomes peopled with minute plants, when Spring sets in, we can form little conception, for a single one may become a thousand in two or three days, and a million by the end of a week. In a particular case, Professor Zacharias notes that within ten days the numbers may be increased sixfold, and that there may be over 70,000 (72,950) in a single litre.

THE RETURN OF THE BIRDS

THE migration of birds is one of the most striking, as it is one of the most beautiful, of seasonal phenomena. Their regular coming and going, often compared to the flow and ebb of tides, has excited the admiration of the observant in all ages. "Yea," the Hebrew prophet said, "the stork in the heaven knoweth her appointed times; and the turtle and the crane and the swallow observe the time of their coming," and still we wait expectant in the Spring for the return of the cuckoo and the nightingale, or watch wonderingly in the Autumn the departure of those birds "who change their season in the night, and wail their way from cloud to cloud down the long wind."

Regarding the flow and ebb of the feathered tide our ignorance is still immense, but that is no reason for leaving the subject severely alone till its formulæ can be stated. Much has been discovered in regard to migration; much is in process of being discovered; there is always fascination in a subject which is developing. The Indians used to name some of the months after the conspicuous migrants; and whether we understand the why and how of the movements, they are certainly before us to be seen, enjoyed, and puzzled over. We shall confine ourselves in this chapter to a statement of the fundamental facts, leaving till later any discussion of the problems or of the methods of investigation.

(1) In the Northern Hemisphere, migration is a very

PUFFINS AT THEIR BREEDING-PLACE

(II)

general phenomenon, but it varies greatly in its conspicuousness—that is, as to the number of birds taking part at one time, and as to the length of the flight. Gätke tells us that from ten o'clock on the night of the 28th October 1882 to early next morning, golden-crested wrens eddied round the lighthouse at Heligoland thick as flakes in a snowstorm, and that they covered every square foot of the island. In the same year, about the beginning of the second week of October, flocks of the same beautiful birds were simultaneously observed at all the lighthouses, lightships, and many land-stations from Guernsey in the south to Bressay among the Shetlands in the north. That is to say, the breadth of the marching column was something like 640 geographical miles. In other cases, the migration occurs without our seeing any excited crowds; yesterday they were with us, and to-day they are gone.

In Britain most of the mass-movements of migrants take place at night, so that we get little impression of the enormous numbers, except when they call as they pass overhead, or are drawn, especially on misty nights, within the bewildering fascination of the lighthouse. The lighthouse-keepers and ornithologists who have been allowed for a time to bear them company, have sometimes great experiences "—of birds in countless hosts, drifting by in feathery tides; birds passing for days together, literally square miles of them; birds by day and birds by night, flying in regular steady waves or in bewildering rushes."

> "Who can recount what transmigrations there
> Are annual made? What nations come and go?
> And how the living clouds on clouds arise?
> Infinite wings! till all the plume-dark air
> And rude resounding shore, are one wild cry."

And as to the distance travelled, it may be from Scotland to Ireland, as seems to be true of some peewits; or from

Eastern to Western Scotland, as with many starlings; or from hill to valley, or from moorland to shore. We have been able to prove that a thrush may migrate from Aberdeenshire to Lisbon, and a black-headed gull to Bordeaux, but these are only short journeys—probably parts of a longer prospective journey in the cases mentioned. It has been proved that storks from Germany may migrate to Natal, and of some other birds it may be said with confidence that they fly half across the earth. The Curlew Sandpiper and the Knot breed so far north that their eggs have rarely been found, and yet the birds have been seen in New Zealand in winter! "They must have performed a southern flight equal to nearly half the circumference of the globe."

Even more striking is the very interesting fact reported by Dr. W. S. Bruce of the *Scotia*, that the Arctic Tern was observed "wintering" in the Antarctic summer in 74° 1′ S. lat. It is well known as a breeding bird on our own coasts to 82° N. lat. We have here, so far as is known, "the greatest latitudinal range of any vertebrate animal."

(2) In the Northern Hemisphere most birds migrate between a colder area which love enlivens, where they breed, and a warmer area where hunger is avoided, where they winter. It is a cardinal fact, to which there are few exceptions, that birds breed in the coldest part of their migratory range.

In emphasising the fact that most birds in the Northern Hemisphere are migratory, and that in a perfectly definite way, we must, however, make it plain that the range of the migration may be very limited, and that many kinds of birds are only partial migrants, some individuals leaving the country and others staying. In many cases the migration is greater than it seems, because the place of individuals that have slipped southwards in Autumn may

be taken by other birds who come to Britain from the Continent.

The broad fact that birds breed in the coldest part of their range implies that the Spring immigrants into a North Temperate country come, on the whole, from the south or south-east, and that the Autumn emigrants fly, on the whole, towards the south. This very general statement is not inconsistent with more detailed statements, for instance, that many immigrants come to Britain from the Continent in Autumn and may swell the throng of our partial migrants.

We have little *secure* knowledge of the precise winter-quarters of those birds which spend their summer with us, but the general fact of an autumnal movement from Arctic and North Temperate Zones to lands nearer the Equator, and of a reverse vernal movement, is certain. Of particular interest are those cases, like that of the stork already mentioned, where the birds "keep always on the summer side of the Equator," where, in other words, they enjoy the northern summer, and, *flying across the Equator*, find a second summer in the Southern Hemisphere.

It must be clearly understood that migration is more than a mass-movement, such as is familiar in the case of Pallas's Sand Grouse, which has repeatedly invaded Britain from the East in considerable numbers. Migration is to be distinguished from gradual extensions of the range of distribution, from tentative explorations in search of food, and from invasions of new territory under urgent stress of over-population. True migration is a regularly recurrent oscillation between a place of breeding and nesting and a place of feeding and resting; it is an adaptation to the seasons and to the conditions of reproduction; the impulse which prompts it is now instinctive, but the trigger is pulled by external stimuli.

(3) In a North Temperate country like Britain, we may divide the birds into five sets, which are not very rigidly limited from one another.

First, there are the *Summer visitors*, such as swift and swallow, cuckoo and nightingale, who arrive from the south and south-east in the wake of Spring, with Spring in their voices. They remain to breed, but leave our shores again in the Autumn. We see some of them congregating excitedly, taking trial flights, as it were saying good-bye many times over ; they start on their journey ; they pass the coast lighthouses in the night ; they traverse the pathless sea ; they speed on, it may be along the west coast of Africa, or across the blue waters of the Mediterranean ; they reach winter-quarters somewhere—in the Nile Valley, in Madeira, in South Africa—somewhere. There they abide until the cold and dark days in the north are past ; thence they return in Spring, some of them at least love-prompted, to our budding hedgerows and reawakened woods.

Among the more familiar Summer visitors to Britain, we may mention cuckoo, nightingale, swift, swallow, martins, ring-ousel, willow-wren, whitethroat, and fly-catchers. The name of the last suggests the obvious remark that the majority of the Summer visitors are insectivorous.

Second, there are the *Winter visitors*, such as fieldfare and redwing, snow-bunting and some northern ducks. They arrive in Autumn, chiefly from the north and north-east ; they are with us during the cold, raw months ; they fly northwards again in Spring, to sing their love-songs—if they have any—in the inhospitable " barren grounds " of the Tundra or amid the surge which surrounds the northern skerries. Many of our Winter visitors in the wider sense come as additions to the ranks of those species that are represented in the country throughout the whole year.

Third, there are the *Birds of Passage* in the narrow sense, such as some of the sandpipers, the great snipe, and the little stint. They occur for a short time on our shores, which are neither warm enough nor cold enough for their constitutions, resting twice a year on their way farther south or farther north. It must be clearly realised that the classification we are using is entirely relative; a bird of passage in one part of the country may be a Summer or Winter visitor in another part. It is similarly necessary to see clearly that the cuckoo is a Summer visitor for Britain, but a Winter visitor for Mediterranean countries.

Fourth, it seems clearest to make another division for those birds that are often called "*partial migrants*"—that are never unrepresented in the country, for while some go, others stay, and the places of those who go are often taken by individuals from farther north. Thus we may see thrushes, lapwings, goldfinches, larks (and many more might be named) every month of the year in Britain, but there is none the less a migration of some of these birds.

Fifth, a few birds seem to deserve to be called "*residents*"—those, namely, that do not leave the country at all, or only in relatively small numbers. The most stationary of the residents is the Red Grouse,—the only bird peculiar to Britain,—which never leaves our shores. But even this bird has its small migration, passing from a higher to a lower level on the hills and moor as the Winter comes on. If would be pedantic, we think, not to class blackbird and robin and house-sparrow among the residents. As we have hinted, however, many birds that seem to be residents are partial migrants; they seem to be always with us, but sometimes careful observation has shown that the individuals are not the same.

Lastly, there are those irregular migrants who may be called "*casual vagrants*"—American birds, for instance,

that somehow make their way across the Atlantic. Thus the Kildeer Plover, a distinctively North American bird, was shot at Peterhead in 1868, and has been recorded since. The occurrence of these " casuals " varies in interest ; in some cases the occurrence is so rare that we may almost call it a curiosity ; in other cases it is repeated year after year, and may indicate an extension of range.

(4) Another general fact admitted by all is that the migratory movements are marked by a high degree of regularity. Whatever it is, migration is not a haphazard business. The same kinds of birds return to the same part of the country about the same time and leave about the same time. The puffin is a good instance of punctuality in arrival, the swift shows the same virtue in its departing. There is some evidence to show that the same pair of birds may return in successive Springs to the same nesting-place, but the only way of making sure of this is to mark the birds. This has been done in the case of house-martin and stork. We can personally vouch for an interesting fact brought out in the course of a Bird-Migration Inquiry now in progress, that a swallow ringed in 1909 came back to the same farm in 1910.

While some migration is always going on, the greater movements are to be seen, as every one knows, in Spring and Autumn. In Spring we look for the return of our singing-birds ; in Autumn they say good-bye again. But the turn of the tide northwards must be put as early as February, when we hear the honk-honk of the wild geese as they make for the north, and see their impressive flying phalanx ; and the turn of the tide southwards must be put as early as mid June when the adult cuckoos begin to get restless, and fly off, leaving their young ones to the care of their duped foster-parents. At present, however, we wish simply to emphasise the fundamental fact of orderliness of movement

both as regards space and time. We shall discuss some of the many uncertainties and some of the difficult problems of migration in subsequent studies. Meanwhile, let us keep the broad facts clear, and realise the wonder of them.

"Any one," Gätke says, "who on dark, starless Autumn nights has heard the babel of voices of these hundreds of thousands and even millions of birds travelling past him overhead, in one fixed direction and in undiminishing numbers for the space of whole months, without the help of any guiding mark discernible by human eye, cannot fail to be led, by the supreme grandeur of this phenomenon, to speculate as to what kind of capacities the unfailing performance of such an act is due; more especially, if like myself he has for more than half a century watched the phenomenon recurring regularly at each solstice with the same unerring precision as the planets in their courses."

SOME QUESTIONS CONCERNING MIGRATION

WE have stated, in the preceding chapter, some of the *general facts* regarding Bird-Migration. These lead on to a series of extremely interesting questions which must be answered very tentatively until more data are collected and critically scrutinised. At the same time, they are not so far from solution as some deeper problems which we propose to discuss in a later chapter.

Since migration, as we have seen, implies an alternation between a relatively colder breeding-place and a relatively warmer wintering and resting-place, the general trend of the journeyings must be from north to south, and back again. But this picture is far too simple. The autumnal north to south flight may end up with a great sweep to the east, and in the north of Europe there is a very important movement from east to west, sometimes with a final sweep towards the south.

"On dark autumn nights," Gätke says, "the sky is often completely obscured by vast multitudes of plovers, curlews, godwits, oyster-catchers, greenshanks, sandpipers, and many other less vociferous species, such as larks and thrushes, whose voices, resonant from afar, proclaim clearly through the stillness of the night from what direction in the sky they are arriving, while the notes of the departing travellers, gradually growing fainter and fainter, announce in a manner equally distinct in what direction they are continuing their journey. *The whole flight proceeds,*

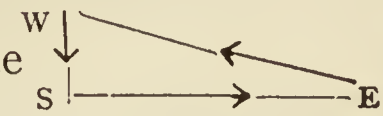
without pause or change, in one incessant stream from east to west."

Hosts of birds gather in Autumn from the plains of Russia and Finland, and pass along the southern shores of the Baltic to Holland or the like, where the direction is turned southwards. Certain contingents seem to follow the valleys of the Rhine and Rhone, thus finding their way to the Mediterranean, and across that to North Africa. Other contingents seem to follow a coast route, crossing, it may be, by Heligoland to the South of England, and thence across to France and Portugal, but finally landing, like the others, in North Africa.

For some birds there is a considerable body of evidence as to the routes followed. The common swallow, for instance, seems on the whole to fly north and south. Large numbers are seen in Autumn making their way down the west coast of Africa, perhaps reaching the Cape; those from Eastern Europe are said to work their way southwards by the Nile Valley. Corresponding species or varieties in North America seem to fly to Brazil, and in North Asia to Burmah.

In illustration of a north to south movement, Gätke cites the case of the Red-Spotted Bluethroat. Those that breed in Norway are supposed to winter in North-East Africa; those that breed in Kamchatka are supposed to winter in South Asia. That those moving from Norway southward do not veer to the west, is indicated by the absence of the bird from France and Spain and its great rarity in England.

Gätke was very strongly of opinion that the vernal flight was *more direct* than the autumnal. Of the birds that pass through Heligoland in Autumn, not more than half, he said, return by that route in Spring. The others cut across. Indeed, as Gätke put it, if the autumnal flight

be represented by the perpendicular and base of a right-angled triangle 

, the vernal flight may be represented by the hypotenuse. When the autumnal flight is altogether from north to south, the vernal flight cannot be more direct; but, as we have seen, there are many birds which show in Autumn an east to west and then a southerly movement. As facts accumulate, it will be possible to test Gätke's interesting suggestion as to the greater directness of the Spring flight, which, as yet, somewhat outstrips the evidence. If there is this marked change of flight in Spring, it will increase the difficulty of understanding the path-finding.

We are still very much in the dark in regard to the termini of the autumnal southward flight, and it is a great satisfaction to be able to point to definite facts secured by ringing individual birds. Thus Dr. Thienemann has proved up to the hilt that many North European storks winter in North Africa and go as far south as Natal. That a large proportion of our Summer visitors go to Africa is probably true, but definite information is scanty. What is known in most cases is simply that no birds of a particular kind are left in Autumn in a northern country, and that there is a practically simultaneous arrival of a large representation of this particular kind of bird in a southern country. But it is a big step from this general fact to the particular statement that night-jars from the English Lake District go to East Africa by the Great Lakes. Yet it is this kind of statement which one desires to make.

A second question in regard to which we lack adequate information is as to the altitude of the migratory flight. There is much reason to fear that many of the statements made in this connection are greatly exaggerated. Observers with telescopes have seen birds crossing the moon's disc

at a height of 5 miles, and have even identified them as woodpeckers and so forth. Mr. F. Chapman saw no fewer than 262 in five hours. Gätke was of opinion that many migrating birds, such as curlews, in full flight keep at an elevation of 10,000 ft. or more; while Eagle Clarke notes that he saw enormous numbers of larks, starlings, and thrushes flying very low across the North Sea. It is probable, however, that these low-flying birds form a small minority. Careful observers have recorded hearing the voices of crowds of migrants passing overhead on dark nights, and have argued from the distinctness of the notes that the birds could not be very high. It seems unlikely that birds habitually fly at a height of anything like 10,000 ft., for that would involve the serious disadvantages of rarefied air and low temperature. On the other hand, if low flying is common, we ought to see more migration than we do. The fact is, we do not know much about the altitude of migratory flight.

A third question which cannot be answered without more data concerns the velocity of the migratory flight, in regard to which startling statements are often made. It seems reasonable to allow that migration represents a climax of activity, when the organism is attuned to great deeds, the easy-going bird flying swiftly, the low-flying bird ascending to higher strata, the diurnal bird flying by night, and so on; but the estimates which even experts have made of a rate of 200 miles an hour require to be substantiated.

Two or three methods have been tried, *e.g.*, observing the time birds took to pass from one visible point to another; observing the time a bird of known size took to become invisible; and arguing from the absence of records of a bird's occurrence *between* two countries, A and B, that the bird flies from the one to the other without stopping. Gätke

observed that curlews, godwits, and plovers went 4 miles in one minute—a prodigious rate if it could be kept up. It is, however, obviously fallacious to infer from the rate of a sprint how much could be covered in an hour.

It is interesting to notice Gätke's reference to an old story of Henry II.'s falcon which escaped from Fontainebleau and was captured twenty-four hours later at Malta. Thirty-six miles an hour! some have said in astonishment; but the knowing old ornithologist pointed out that the speed must have been at least twice as great. The falcon rested during the night, did a little hunting, had a meal and a digestive rest, and did not hurry after all!

Yarrell mentions the fact that in a race from Ghent to Rouen a carrier pigeon flew at the rate of 100 geographical miles in an hour, but Gätke regarded this as a very mediocre performance. By collating observations with John Cordeaux in England in regard to flocks of hooded crows crossing from Heligoland to Britain, Gätke arrived at the result (certainly open to suspicion) that these birds fly at a rate of 108 geographical miles per hour, doing 320 miles in about three hours. The possible—perhaps probable—fallacy is obviously that the flocks whose times of starting and of arrival were carefully noticed may not have been the same flocks at all. But 108 miles per hour is nothing like the pace of some other birds! The Northern Blue Throat (*Cyanecula suecica*), a little bird like a robin, flies in Spring from the Nile and Central Africa (10° to 27° N. lat.) to Northern Europe, to Heligoland by the way. It reaches Heligoland about dawn. Because the bird is very rare in intermediate areas, having only a very isolated occurrence, Gätke concluded that it flies *continuously*, and there are several other facts suggestive, though not demonstrative, of this conclusion. At all events, Gätke's

data led him to the remarkable result that the bird accomplishes a journey of 1600 miles or so in nine hours, that is, at a rate of 180 geographical miles per hour. But if this speed can be attained by the blue-throat, what may we not believe of really swift birds, such as hobby, swallow, and plover. The Virginian Plover (*Charadrius pluvialis*) is believed (by those who are satisfied with the assumptions) to pass in one magnificent flight of fifteen hours from Labrador to North Brazil, about 3200 geographical miles. That would correspond to a velocity of 212 geographical miles per hour, and we shall draw the line here.

Tegetmeier has given facts which show that a carrier pigeon may keep up a rate of 55 miles an hour for several successive hours, and by many observations on herons crossing a narrow strait I convinced myself one holiday that a mile a minute is not an exaggeration. It may be recalled that large birds, such as pheasants, have been known to fly right through plate-glass shop windows, which indicates a high velocity.

While admitting that facts are few, we venture to adhere to the idea that the migrational flight at its height may well be something far above the ordinary performance. For in migration the bird is often at high tension; as we have already noticed, low-fliers sometimes fly high, diurnal birds may fly by night, easy-going birds may attain to great speed. If we succeed in forcing a corncrake to winged flight in this country, we see a somewhat lumbering performance, which gives little hint of what the bird can do in migration.

Contrast of Spring and Autumn Flight

As we have seen, the Spring flight is in great part northward, the Autumn flight in great part southward;

and, speaking in the same rather vague manner, we may say that the spring-tide is moved by "love" and the autumnal-tide by "hunger." Although the subject requires more exact study, we may admit that there is some truth in what many observers have stated as to a difference in the *character* of the movement at the two seasons.

The Autumnal movement is relatively less intense; there is more dallying—at least, till they get fairly agoing. In some cases, as Mr. Eagle Clarke points out, the reason is obvious: "Food is still abundant in their favourite resting haunts, and there is no particular hurry to move southwards."

Of the Spring movement, Gätke says "unrest and impelling haste are everywhere the prominent characters"; there is no division of the journey into stages, nor any tendency to long spells of rest. "Das ewig weibliche zieht sie heran."

As to the *order* of flight, likewise, one wishes that there were more security. Gätke's conclusions in regard to the 396 birds studied in passage at Heligoland were, in the main, three: that the Autumn migration is (with one exception) initiated by the young birds, which begin to move about six or eight weeks after they leave the nest; that the parents of these young birds do not get restless till a month or two months later; and that among the adults the handsomest old males are the last to set out on the migratory journey. In Spring this order of succession is reversed; the gay old males are the first to arrive, and the immature young birds come last. The exception referred to above is, of course, the cuckoo, for the parents leave long before the young ones, which they have foisted on to the care of other birds.

In his *World of Life*—a remarkable achievement for a

veteran of eighty-eight—Dr. Alfred Russel Wallace has severely criticised the view that the young birds make the autumnal journey alone. He admits Gätke's observation, with which the Heligolanders used to be practically familiar, that the young birds arrive first and alone, the adult birds appearing a week or two later. But he rejects the inference that the young birds start on their migration alone, and before their parents. According to Wallace, what probably happens is this: that the older birds and stronger young ones, flying together, pass over Heligoland without stopping; that those young birds that sink down on Heligoland are the weaker individuals, much fatigued; and that those adults that arrive later on the island do not represent by any means the main contingent, but rather the crippled, the unmated, the partially moulted, and so on. On this view, he thinks, "all the facts are explained without having recourse to the wildly improbable hypothesis of flocks of immature birds migrating over land areas and sea quite alone, and a week in advance of their parents or guides."

This criticism is a useful one, and certainly the marvel of migration is great enough without being gratuitously enhanced. On the other hand, practised ornithologists develop observational power to a very remarkable degree, and there are numerous testimonies to the fact that great crowds of young birds have been seen leaving British shores before the adults have got on the move, and that great crowds of young birds have been seen arriving on our shores from the Continent in Autumn with, as far as could be detected, no adults amongst them. It is, indeed, practically impossible to be sure that there are no old experienced hands among the youngsters, but of their apparent absence there is considerable expert evidence. Moreover, it should be pointed out that, even on Dr. Wallace's interpretation of

the data, we have to face the fact that, whether the young birds that alight on Heligoland started alone or not, they have to leave the island again without adult guidance.

In the presence of considerable information in regard to a number of birds, we adhere to the view that in many cases the young are the first to start on their southward journey in Autumn and the last to arrive on their return journey in Spring. Even among the adults there is sometimes a curious separation of the sexes—possibly because they fly at unequal rates.

That the old birds should delay longer than their children is not in itself surprising, for many of them require rest after the arduous labours of nest-making and feeding the young. Moreover, many of them have to undergo a moult before they start, and from this the young are exempt.

Another matter, in regard to which generalisation is rash because data are few, is the influence of weather on migration. It seems likely that the weather conditions that obtain when and where a mass-movement *begins* are of more moment than those into which the birds pass in the course of their flight. Puffins, for instance, arrive on our coasts with extraordinary punctuality, no matter what the weather is like. It is certain, however, that unfavourable weather may involve enormous increase of mortality, which is probably always very high, and may even put a stop to the flight altogether. Very dense fog and a head-on gale may make flight impossible. Mr. Eagle Clarke has supplied definite facts as to the delay of some migrations by stormy weather, but he admits the general statement that birds in their movements seem to be very indifferent to meteorological conditions. As to the fact often referred to, that many birds are seen

migrating southwards in Autumn with the north wind behind them, it has been justly observed that this is because the weather conditions that have prompted the birds to start are also those which cause a north wind to blow across Britain.

REAWAKENINGS

THE welcome one gives in Spring to the returning swallow and cuckoo soon broadens. There are many old friends, and there is a thrill in the first sight of each of them. For this one has been in the Far South, this other in disguise; one has been in hiding, and another has gone down in sleep to the very gates of death. As an instance of those that are reawakened, we may take the humble-bees, which reappear in April or May. Queens or females, they are—sole survivors of last year's brood, who have passed the Winter at rest in some sheltered hole in a mossy bank.

They fly to the early flowering plants, such as the willows, from whose fragrant catkins they get their first meal. There is a dwarf willow on the golf-links, one of the smallest of trees, not more than a couple of inches in height, and it is there that we find the newly roused queens year after year. After some recuperation they look out for a suitable nesting-place, where they make a more or less bowl-like cradle of wax, containing a small quantity of pollen mixed up with nectar. In this mass several eggs are laid, and then the cradle is closed. After a short rest the queen goes on to make a second cradle or cell connected with the first, and then a third, and so on, each with its batch of eggs and a small store of food. The store is so scanty, however, that the developing larvæ soon exhaust it, and the queen has to feed them through a hole made in the lid of the cradle.

After a month or so has elapsed the first brood emerges,

each member from within its silken cocoon. These are all "workers,"—that is to say, usually sterile females,—but they are not structurally different from the queens, as the worker hive-bees are. The first set of daughters begin to help the queen-mother to collect provender, and soon there is a second set. The queen ceases to forage and remains in the nest, exclusively maternal. Some of her daughters may produce eggs, which develop without being fertilised. In any case, towards the end of Summer numerous drones or males are produced and several fully developed females—the future queens.

Thus there is a large family—consisting of one queen-mother, many workers, a smaller number of drones, numerous young queens, and, it may be, some grandchildren. A nest of *Bombus terrestris* in August contained 35 young queens, 20 drones, and 160 workers. The average number of a colony of *Bombus muscorum* in Britain is said to be about 120—namely, 25 females, 36 males, 59 workers. But the family as such is shortlived, thus differing markedly from the bee-hive. All the members die off in the Autumn, except a few fertilised queens, which rest, as we have seen, throughout the Winter.

The nest of the humble-bee, which country boys often destroy for the sake of the honey, is at a far lower level of architecture than that of the hive-bee or the wasp. The cells are of different sizes, those of the queens being largest, of the workers smallest. They are not regularly arranged in tiers, but a second set is built on the ruins of the first. No cell is used twice as a cradle, but an old cradle may be used for storage. An understanding of the nest is not facilitated by the fact that some of the cells are built, not by *Bombus*, but by a friendly parasitic bee (*Psithyrus* or *Apathus*) that lives in the humble-bees' nests. Dr. David Sharp writes :[1]

[1] *Cambridge Natural History*, vol. vi. p. 57.

"A nest of *Bombus*, exhibiting the various pots projecting from the remains of empty and partially destroyed cells, presents, as may well be imagined, a very curious appearance. Some of the old cells apparently are partly destroyed for the sake of the material they are composed of. Others are formed into honey-tubs, of a makeshift nature. It must be recollected that, as a colony increases, stores of provisions become absolutely necessary, otherwise in bad weather the larvæ could not be fed. In good weather, and when flowers abound, these bees collect and store honey in abundance; in addition to placing it in the empty pupa-cells, they also form for it special receptacles; these are delicate cells made entirely of wax filled with honey, and are always left open for the benefit of the community. The existence of these honey-tubs in bumble-bees' nests has become known to our country urchins, whose love for honey and for the sport of bee-baiting leads to wholesale destruction of the nests. According to Hoffer, special tubs for the storing of pollen are sometimes formed; these are much taller than the other cells. The *Psithyrus* that live in the nests with the *Bombus* are generally somewhat larger than the latter, and consequently their cells may be distinguished in the nests by their larger size. A bumble-bee's nest, composed of all these heterogeneous chambers rising out of the ruins of former layers of cells, presents a scene of such apparent disorder that many have declared that the bumble-bees do not know how to build."

There are many points of fascinating interest in respect to humble-bees. There is the extraordinary industry throughout the summer—the collecting of pollen and nectar from the flowers, the making of the cells in the nests, the feeding and tending of the young. It is difficult to refrain from quoting too much from Dr. Sharp's great contribution to Entomology; we venture to give one of his notes on

EARLY FLOWERS AND HUMBLE-BEE

(III)

industry : " Some work even at night. Fea has recorded the capture of a species in Upper Burmah working by moonlight, and the same industry may be observed in this country if there be sufficient heat as well as light. Godart, about two hundred years ago, stated that a trumpeter-bee is kept in some nests to rouse the denizens to work in the morning : this has been treated as a fable by subsequent writers, but is confirmed in a circumstantial manner by Hoffer, who observed the performance in a nest of *Bombus ruderatus* in his laboratory. On the trumpeter being taken away, its office was, the following morning, filled by another individual. The trumpeting was done as early as three or four o'clock in the morning, and it is by no means impossible that the earliness of the hour may have had something to do with the fact that for two hundred years no one confirmed the old naturalist's observation."

The inter-relations of humble-bees with other living creatures are manifold. Darwin has shown how they form a link in the chain that binds cats and clover-crop, and they are similarly bound up with the pollination of many other flowers. They have numerous enemies—the field-mice that burglar their nests, many insects that destroy the larvæ, and at least one bird, *Merops apiaster*, the bee-eater. Numerous mites are often seen on their bodies.

Perhaps the most extraordinary feature in the economy of *Bombus* is their tolerance for their *Doppel-Gänger*, *Psithyrus*, which are inmates of their nests. Host and guest are like one another : " They were not distinguished by the earlier entomologists ; and what is still more remarkable, each species of *Psithyrus* resembles the *Bombus*, with which it usually lives. There appear, however, to be occasional exceptions to this rule, Smith having seen one of the yellow-banded *Psithyrus* in the nest of a red-tailed *Bombus*. *Psithyrus* is chiefly distinguished from *Bombus* by the

absence of certain characters that fit the latter insects for their industrial life; the hind tibiæ [fourth joints of the leg] have no smooth space for the conveyance of pollen, and, so far as is known, there are only two sexes—males and perfect females. The *Bombus* and *Psithyrus* live together on the best terms, and it appears probable that the latter do the former no harm beyond appropriating a portion of their food supplies. Schmiedeknecht says they are commensals, not parasites; but it must be admitted that singularly few descriptions of the habits and life-histories of these interesting insects have been recorded" (Sharp, *loc. cit.* p. 59).

When there are too many guests, the family remains small, but the relations of host and guest remain quite friendly. The arrival of a new guest creates apparent excitement, but there seems to be some fascination about the big, lazy intruder. A well-established friend of the family is said to resent the appearance of a newcomer. Altogether, the association is a strange riddle.

Humble-bees are very familiar animals, but there is still much to be learned in regard to their ways—what determines the production of workers, drones, or queens, what time is required for the development of each, what determines the occasional parthenogenesis of workers, and so on. These and other points, such as the great variability in the colour of the abundant hair, require further investigation, which is sure to be richly rewarded.

It is impossible to pass from the humble-bee without noticing the interesting position it occupies in the evolutionary series of bees. Let us run up the scale.

First, there are solitary bees like the leaf-cutter, *Megachile*, who bores a tunnel in wood, lines the end of it with neatly cut pieces of rose-leaf, deposits pollen, nectar, and eggs, shuts the door, and flies away.

Second, there is a stage represented by a rare bee,

Ceratina, who behaves as the leaf-cutter does, but waits about till her young ones are hatched, and then flies away *with them*.

Third, there are mining bees, like *Andrena*, that make many tunnels in one place, with a distinct tendency to be gregarious, though each digs a distinct hole for itself.

Fourth, there is the stage represented by *Halictus*, where several combine to make a burrow or street in the sandy bank, and then dig their respective tunnels opening separately into it.

Fifth, there is the temporary community represented by *Bombus*, where only the queens survive the Winter. But it is very interesting to notice, especially in connection with seasonal punctuation, that just as there are some northern humble-bees that have no workers and no community, so there are some southern humble-bees, as in Corsica, which survive as a big family or incipient community through the Winter.

Sixth, the climax of the series is reached in the permanent society of the hive-bee, where workers as well as queens live through the Winter.

SPRING FLOWERS

EVERY observer will admit that there is a certain regularity in the succession of flowers in the course of the year. Most of them have their times of appearing, just as the birds have. To find a foxglove or a viper's bugloss blossoming in early Spring, or wood-anemones and wild hyacinths in late Summer, would surprise us as much as to see a full-grown cuckoo in Autumn. It is interesting to try to analyse the order of this seasonal procession or pageant, though we may not be able to do so with much success.

Perhaps we may arrange the early Spring flowers in four groups. There are not a few, such as willow, hazel, alder, dog's mercury, and so on, that have very little in the way of decorative parts. In many cases they are practically reduced to the essentials—stamens and carpels. There are relatively few flower-visiting insects at this time of year, and a large proportion of the earliest flowers are pollinated by the wind. In a second group we may rank those, like the Hellebores, that have their petals and sepals (or perianth parts) of a greenish colour—that is to say, not very far removed from the normal green-leaf type. Thirdly, there is a noteworthy group of early Spring flowers that are white. The wood-anemones, which rise in the wood from amid the withered leaves and toss in the wind like foam-balls, illustrate this type, and snowdrops, wood-sorrel, and sloe-blossom immediately rise in the mind. There is such a thing as white flower-pigment (antholeucin),

but in most cases the petals or sepals are white, just as foam is white, because of innumerable gas-bubbles in the cells. They may be literally spoken of as living foam. Fourthly, there are brightly coloured Spring flowers, like the tulips and irises, that make even the steppe country resplendent, or the marsh marigolds in our ditches and the wild hyacinths in our woods.

One of the most obvious general facts is that all the Conifers in North Temperate countries flower very early in the year—in March, April, and May. This is interesting when we remember, what every one knows, that they represent a much older stock than the ordinary flowering plants. It is proved by their structure, and also by their history in the rocks, that " Gymnosperms " are much more ancient than " Angiosperms." Why should they all flower early ?

It is probable that numerous factors contribute to this result. First of all, they are trees, with a large store of potential energy and in a very different position from annuals, for instance. Secondly, many are thick-skinned evergreens, and therefore hardy, without the usual thorough Winter's break in the assimilation processes. Thirdly, they come of an old hardy stock, much tried for many ages during the evolution of our present-day climate. Fourthly, they are anemophilous—that is to say, pollinated by the wind, and requiring no insects to visit them ; they are, therefore, not prejudiced by flowering at a time of year when insects are scarce.

A general fact to be borne in mind when thinking of our early Spring flowers is that most of them blossom so soon in virtue of stores previously acquired. It is plain that trees have, on the whole, the start of herbs because of their perennial stems and branches, which mean not only a great store of potential energy, but also the

possibility of having ready-made buds in position for unfolding. In some cases, such as the alder, even the flower-buds are made the previous Summer. It is interesting also to notice, what Grant Allen points out, that many of our early flowering trees, like lilac, hawthorn, and laburnum, are plants which have a long life before they flower. They have a prolonged nutritive or vegetative period before reproduction begins, and this is doubtless one of the conditions of their hardiness. Another, even more frequent, adaptation to early flowering is the possession of an underground store in the form of rhizome, corm, or bulb, as may be illustrated by dog's mercury, primrose, coltsfoot, celandine, hyacinth, and snowdrop.

While those Spring flowers that have only stamens and pistil may be regarded as persisting on *primitive* lines, there are others which may be regarded as persisting on *juvenile* lines. We mean that they tend to be bud-like—as if some slight arrestment occurred in the opening of the blossom. This may be illustrated by crocus and globe-flower.

Another general impression that we get when we take a wide survey is that the colours of the early flowers are lighter than those of summer, and that colours deepen as the sunshine increases. Of course, there are many exceptions; but many of these, such as tulips, hyacinths, daffodils, crocuses, irises, are bulbous plants, which places them in a very different position from ordinary annuals and biennials. The whole subject of pigments, alike in plants and animals, is exceedingly difficult, and one must beware of hasty generalisation. The same colours may depend upon different pigments; the same pigment may have different colours; a very slight change in the alkalinity or the acidity of the cell sap may produce a great difference in the colour of a pigment. And while progress

has been made by a number of valuable studies, notably Dr. Marion Newbigin's *Colour in Nature*, our knowledge of the composition, origin, and primary import of pigments is still scanty. With this caution in mind, we adhere to the thesis that the heightening of colour is associated with the increased intensity of sunshine, though this does not necessarily mean that the correlation is one of direct cause and effect. It is plain, for instance, that most of the flowers are adapted for insect-pollination, not wind-pollination, and it may be argued that the flower-visiting insects —which increase in number as the Summer sets in—have throughout long ages consistently selected the variants in the direction of brighter coloration. But we must return to this subject.

In a very interesting essay on "The Philosophy of Flower Seasons" (*American Naturalist*, 1893, pp. 769–781), Mr. Henry L. Clarke has maintained the thesis that the more primitive flowers tend on the whole to appear earlier. Let us illustrate his line of argument.

Though there are among Monocotyledons some very highly specialised forms, such as orchids in one direction and grasses in another, it is generally admitted that Monocotyledons represent a lower grade of evolution and an older stock than most of the Dicotyledons.

Now, what place do the Monocotyledons take in the year's procession? Think of snowdrops, daffodils, irises, wood hyacinths, and so on. The *general* statement is surely that, apart from specialised forms, the great majority of Monocotyledons flower in Spring or early Summer. The specialised grasses, on the other hand, culminate in Summer, and some continue on into Autumn. The less specialised sedges are distinctly earlier, thus the genus *Carex* culminates in May, though the type-genus *Cyperus* belongs to August and September. Similarly, Liliaceæ

predominate in Spring, though, again, the type-genus *Lilium* culminates in Summer. The highly specialised Orchidaceæ are distinctly Summer flowers.

Likewise, among the Dicotyledons, it will be allowed that the hypogynous forms with superior ovaries are more primitive than the epigynous forms with inferior ovaries, and the dialypetalous condition more primitive than the gamopetalous condition. Here, again, the more primitive come first.

Earliest of the hypogynous flowers are the Ranunculaceæ: celandine and buttercup, hepatica and anemone, marsh marigold, and so on, appear early—all "wearing the trembling pearls of Spring." But the more specialised forms, such as columbine, larkspur, and monkshood, are later, and some clematis belong to Summer. But most of the typical Hypogynæ are Spring flowers. The Rosaceæ, perigynous forms, are later in starting than the more primitive Ranunculaceæ, and reach perfection in late May and through June.

"Turn," says Mr. Clarke, "to the Epigynæ: Caprifoliaceæ (honeysuckle) and Rubiaceæ (bedstraws), though scattered, predominate in Summer; Campanulaceæ, particularly in late Summer and in Autumn, the finest type, *Campanula americana*, coming in September. Late in Summer and in September the Lobeliaceæ are in fullest perfection, the splendid *Lobelia cardinalis* and *L. syphilitica* being late. And lastly, we meet the vast order Compositæ, undoubtedly nearly the highest of flowering plants. So numerous a group would naturally spread throughout the seasons; but, mark, it comes in all its glory late in August and straightway through the Autumn, when we have, among many, those gorgeous genera, *Solidago* (Golden rod) and *Aster*. Here the fact confronts us that in the Autumn the higher Sympetalæ hold sweeping predominance over the lower Choripetalæ."

The same general induction may be reached by singling out highly specialised forms belonging to certain orders, and noting that they appear usually later than their more average relatives. The pondweeds (*Potamogeton*), peculiarly specialised among Naiadaceæ, come late; Smilax, a Midsummer flower, is markedly more specialised than the Spring-flowering Liliaceæ; Columbine comes after Celandine; of aquatic Nymphæaceæ (near relatives of Ranunculaceæ), the most specialised Nelumbo is latest to flower; Grass of Parnassus, an aberrant relative of the Saxifrages, belongs to late Autumn, and the Sundew also flowers in late Summer; the aquatic Bladderworts are wholly Summer flowers; and so on through a long list.

Yet another mode of approach is to take a single genus, and follow its species. Mr. Clarke takes the Slipperwort (*Cypripedium*). "Earliest, in late May, comes the little white *C. candidum*; a little later the low, stemless type with its large complicated flower, *C. acaule*; still later the small flowered but tall-growing *C. parviflorum*; later yet, the large cousin of the last, *C. pubescens*; and latest, late in June, most robust, vigorous, and conspicuous, the splendid *C. spectabile*."

Let us hear the conclusion of this interesting inquiry into the succession of flowers in their seasons. "From early Spring to late Autumn there is a progression in the general character of the flower-groups, from the lower to the higher—successive groups succeeding each other in time, parallel groups coming synchronously. The later in order may be types of a higher character of development, or they may be specialisations of a group whose normal forms belonged to an earlier season. In short, in their blooming season, the more perfect succeed the more simple; the aberrant, the normal; the specialised, the generalised."

While Mr. Clarke's thesis seems to have a considerable body of evidence to support it, we cannot regard it as more than a partial interpretation. The problem is a complex one, and, as Mr. Clarke recognises, the time when a flower blooms is a function of many determinants, both fixed and variable. It may be of interest to tabulate these.

(1) Much depends upon the plant's peculiarities of constitution; thus those that have stores of reserve material, which means energy, in corm and bulb, tuber and rhizome, stem and evergreen leaves, will be able to flower earlier than those that have no reserves.

(2) Of importance also is the nature of the plant's habitat and its availability at different seasons. "The Spring flowers seek largely the protection of the woodlands; marsh plants reach perfection mainly in latest Spring and through the Summer, though some, like Caltha, are early; the aquatics of ponds and river glory in the Summer sun; and the flowers of meadow and prairie and thicket margin luxuriate from Midsummer to the end of Autumn."

(3) Another factor is the mode of pollination; by wind or by insects, and by some kinds of insects rather than others. It is plain that we cannot look for a large proportion of insect-pollinated flowers in very early Spring. It is true that insects may, in the course of time, adapt their life-history to suit the flowers on which they depend, but it is obvious that a bee-pollinated flower is not likely to survive if it takes to blossoming only at a time when there are no bees about.

(4) Something must also be allowed for the geographical origin of any particular plant. A wanderer from a colder country will naturally flower early in its new home.

(5) After allowing for these (and probably other) factors, we return to the thesis that the time of flowering

SPRING: LUPINS AND OYSTER-CATCHER

(IV)

depends to some extent on the plant's position in the evolutionary series. The simpler, the more normal, the more generalised, in short, the older, tend to flower first.

"The most simple and generalised forms, coming first in the course of floral evolution, have had longest time in which to adapt themselves to existing climatic conditions; and, reciprocally, climatic conditions have become more and more favourable to the rapid development of the said forms. So a floral type that ages ago would have reached its perfection only after a long continuance of favouring seasons, now may burst into the fulness of its maturity with the first warmth of Spring.

"But as change succeeded change, in the course of time a maximum point would be reached, from which the conditions would become less and less favourable to the rapid development of types surviving from an earlier age. Then these would dwindle from the earth—replaced, driven out, by those that had come into existence in a later age.

"Thus, in the ages to come, the early flowers of to-day will disappear, to be replaced by what are now our later flowers; whose place, in turn, will be filled by forms that are yet to be."

Let us therefore be glad in the Spring flowers which, like ourselves, are children of a day.

Let us, as Solomon said, crown ourselves with rose-buds before they be withered.

BOOK II.—SUMMER

BOOK II.—SUMMER

IMPRESSIONIST SKETCH

THE tide which begins to rise in Spring reaches high-water mark in Midsummer, when it often makes for itself a new shore. The buds are replaced by leafy boughs, activity during the day is intense ; the bud-like early flowers are succeeded by others of more liberal beauty ; young things pass through adolescence to mature strength ; and Love is justified in her children. For Summer is the time of maximum output and income of energy, when the fires of life not only burn brightest, but are built up for another season ; it is the time of intensest effort, rising even to madness, the time of richest beauty and fullest joy.

Although we are wont to associate Summer with rest and holiday-making, this is an urban, not a rustic, generalisation. Midwinter is the countryman's resting-time ; in Midsummer he is hard at work. So with Nature, for in Summer most work is done, and great stores of energy are accumulated for another year.

Whether we think of the green leaves in which the powers of light and life co-operate to raise simple substances into complexity, the inorganic into the organic ; or of the bees who so industriously visit the flowers and store up honey in the hive ; or of the birds gathering food for their callow young ; or of the haymakers busy in the heat of the day, we get the same impression of vigorous work, at the various

planes of unconscious, instinctive, intelligent, and rational life.

The biggest fact in the Biology of Summer is perhaps the most obvious one, that it is then that life comes nearest, or, what comes to the same thing, is most exposed to the source of all mundane energy—the sun. Thus the Biology of Summer has for its central problem the influence of heat and light upon life. Now there is heat that burns, as we see in the Steppe vegetation after the dry season; and there is light that kills, notably in the case of the disease germs or Bacteria which a forenoon of clear sunshine destroys so beneficently; but the general fact, demonstrable by numberless experiments, is that the heat and light of Summer renew the energies of living creatures. Indeed, we all depend from year to year on the power that green plants have of inducing the sunlight to help them to make food for us.

At the very opposite end of the scale—for there is a long gamut of life from wheat plant to man—is it not true that seeking the sun and seeking more life are synonymous for some of us? It is well known that the pulse-register or sphygmograph proves that the sunshine vivifies the system. Quite irrespective of warmth and comfort, quite apart from the delights of the holiday mood, of being free, of hearing the birds sing, and seeing the flowers in bloom, the sunlight quickens the pulse and man's life.

> " O solemn-beating heart
> Of nature! I have known that thou art
> Bound unto man's by cords he cannot sever.
> And what time they are slackened by him ever,
> So to attest his own supernal part,
> Still runneth thy vibration, fast and strong,
> The slackened cord along!"

And if in man—so often with a slackened cord—the sunlight still awakens response, how much more in the animals

who throb with every pulsation of Nature's heart. And if the sunlight finds voice in the bravura of birds, how much more directly in the bustle of growing wheat!

The growing intensity of unconscious vegetative life is registered in the increasing brightness of floral colour. For although there are many bright flowers in early Spring—the marsh marigold, which raises its golden cups from the dank ditch; the bright yellow celandine, which welcomes the swallow; the blue hyacinths, which make the wood-glade glorious—"the heavens upbreaking through the earth"; the laburnum, with its "dropping wells of fire"; the periwinkle and the ground-ivy, and the golden daffodils, whose dance "outdoes the sparkling waves in glee"—yet the broad fact is that as the days grow warmer and brighter, the colours increase in intensity. Although we may not be able to accept the meteorologist's suggestion—too simple to be true—that the annual succession of colour corresponds to the colour scheme of the rainbow, yet it seems demonstrable that red and purple, blue and violet flowers, in short, those of richer colour, become on the whole more numerous as the days lengthen.

Ruskin, following Goethe, defined the real nature of the flower when he said, "The leaf which loves the light has, above all things, the purpose of being married to another leaf, and having child-leaves, and children's children of leaves, to make the earth fair for ever. And when the leaves marry they put on wedding-robes, and are more glorious than Solomon in all his glory, and they have feasts of honey, and we call them flowers." For it is admitted by all that the petals are transfigured leaves, and that the pollen-producing and seed-producing parts of the flower are also modified leaves. The feasts of honey or nectar are overflowing wells of sugar in more or less useful places; the fragrance which is so often given off from these creatures that toil not may be

remotely analogous to the musk-like and other odours which exude from the skins of animals ; and the fine colour of the wedding-robes, just like the yellow in some butterflies' wings, is in some cases due to waste products, the ashes of the flowers' hidden fires.

It cannot be said that we have by any means attained to an understanding of either nectar or fragrance or colour ; we are still children with flowers in our hands, just beginning to know something about them. But we have got past the preliminary stage of giving their insect visitors the whole credit of evolving flowers, which is a little too like crowning snakes for evolving the wisdom of the East ; we are now busy trying to find out what nectar, fragrance, and pigments mean primarily or physiologically in the internal economy of the plant. The poet says of the flower : " It must be the flag of my disposition, out of hopeful green stuff woven " ; the religious mind says : " It is the handkerchief of the Lord, a scented gift and remembrancer designedly dropt, bearing the owner's name someway in the corners " ; the biologist says : " Overflow of surplus sugar, sublimated vegetable sweat, and literal beauty for ashes " ;—but the flower in the crannied wall is a hieroglyph still.

Summer, we say, is the time of maximum industry, and greatest of all is the unconscious work of the sunlit leaves. The results of this are seen in the filling of tubers and rhizomes, corms and bulbs, and other storehouses ; in the formation of next year's buds ; in the making of seeds and the swelling of fruits ;—and again, indirectly, in the increased store of potential energy which is thus brought by plants within reach of animal life. The sunbeams dance over the meadow, but some of them are trapped, and their dance is lost in a dance of molecules which change partners in the maze, link themselves in mobile groups, and reach their climax of linkage in complex combinations, some more

stable, some more unstable. Many a meadow is almost iridescent, we can hardly see the grass for flowers, each is in a sense a fixed sunbeam; the butterflies flit from blossom to blossom, the sunbeam is in motion again. It is a ceaseless series of transformations of energy.

That Summer is the time of intensest industry is plain enough even among the plants, but this dominant impression of what Summer means biologically is emphasised when we watch its busy animal life. This is swayed in great part by the twin impulses of Hunger and Love. There is eager endeavour after individual well-being, and there is a not less careful effort which secures the welfare of the young. The former varies from a life and death struggle at the very margin of subsistence to a gay competition in the pursuit of æsthetic luxuries; and the latter rises from physiologically necessary life-losing and purely instinctive sacrifice to what seems to us affectionate devotion. Whether we look out on plants or animals or men during these Summer months of intense life, the old question rises to our lips, "Warum treibt sich das Volk so und schreit?" and the answer, fundamentally true, but changeable within limits for different existences, is ever, "Es will sich ernähren, Kinder zeugen, und die nähren so gut es vermag."

The activity of ants, bees, wasps, and other insects, represents Summer industry at a higher level than that in the leaves. It is behaviour, instinctive behaviour. By behaviour we mean that the creatures follow out a routine whose individual acts are arranged in effective sequence. By instinctive we mean that the behaviour does not seem to require intelligent control, it is more or less independent of education and experience—though it may be improved by both. Most of those activities, which it is one of the delights of Summer to watch, are performed in virtue of inherited cerebral initiatives, if such an ignorance-

confessing phrase be admissible. The animals are, so to speak, constitutionally wound up to do what they do when suitable stimuli occur. In many of their activities they seem to be conscious automata, if we may infer consciousness from the way in which intelligence often takes the reins when something unusual disturbs the routine. But the beauty of it is that the results of the conscious automatism are often as perfect as the outcome of prolonged and profound deliberation. As we look at the bee's honeycomb, the wasp's nest, the spider's web, it seems as if art, in the broad sense of skill, is perfected in becoming most instinctive; and surely the rationality of our world is as plain in the web or the termitary, as it is in the Forth Bridge or the Eiffel Tower.

Animal industry in its instinctive form gives one an impression of ease and spontaneity; they do not sweat or whine, or hesitate or look worried. They remind us of very perfect mechanisms which perform their task without noise or jar, with a fine "smoothness." But just as the machine has certainly its wear and tear, however well concealed that may be, so is it with the instinctively industrious animals. Recent researches prove that the nerve-cells of a bee's brain are, at the end of a hard day's work, unmistakably fatigued; and, more than this, a certain number seem quickly to go out of gear as the Summer's work continues; they die off until no more are left than are sufficient for the necessary vital functions; and finally these also give way. There are hints of the same sad fact even in man; and although our knowledge of the matter is very slight, we may dimly see why it is that we are doomed, not only to become "old fogies," but to die of "old foginess" should we escape a more merciful ending. Along the same line of thought we may perhaps advance to a better understanding of the saving reactions of daily

and seasonal sleep, by which fatigued nerve-cells are recuperated before they have gone too far.

Representing a higher grade of activity than that of the bees, is the parental industry of the birds, for it is to a larger degree intelligent. We do not refer to the building of nests, which we regard as an activity of Spring (often continued into Summer), and as instinctive in greater part; we are thinking rather of the untiring activity which so many exhibit in protecting, feeding, and finally educating their young. The songsters are quieter than they were, the wild lyrics have given place to more measured psalms of life, partly, of course, because the ecstasy of passion is over for the season, partly, perhaps, because the birds have found keeping house a much more serious business than falling in love and getting married. It is such a familiar fact, that we are apt to miss the beauty of it—the manner in which the love of mates broadens into the love of offspring. Every one knows that the two parent birds will work themselves thin in caring for their young. We are not warranted in supposing that the birds think of their sacrifice, any more than of the welfare of the species,—they do not control their conduct in reference to an ideal; they are not moral, poor things,—but is there not something wonderful in it, something, as Socrates said, moving to tears, and yet consoling in our relations one with another?

But it must be noticed that the intensity of life, which seems to us so characteristic of Summer, is by no means unrelieved. Every one familiar with the country has noticed that in days of intense heat the whole aspect of Nature occasionally suggests sleepiness, especially about noon. A few clouds hang motionless in a lofty blue sky, the air is tremulous over the hot earth, the birds are all hushed in the woods, the leaves droop after extreme

transpiration, the labourers have lain down in the shade of the hedge, and there is scarcely a sound save for the grasshoppers, whose interrupted chirping makes us feel the vast background of silence. Doubtless our own sleepiness exaggerates the impression ; but when even the leaves sink into "sleep," saving themselves from too great loss of water, few living things are likely to be wakeful. In fact, what we experience even in this country is a suggestion of the Summer slumbers or æstivation—of mud-fishes, amphibians, and crocodiles, when the waters dry up in the pools of tropical countries. It is interesting to corroborate this impression by visiting certain kinds of shore pools in the heat of the day when there is a stillness like that of an Eastern city in siesta, and in the morning or afternoon when there is all the activity of a Donnybrook Fair.

There is another phenomenon that has often impressed us on a bright and breezy Summer day—the sudden appearance of a dark cloud, which, though heavy with dust and rain, drifts rapidly across the sky. We can follow its shadow as it sweeps over the fields and the firth ; and as it blots out the sun from us for a few long seconds, we feel a shiver of suspense. Of course this is mere sentimentalism, but the precise physiology of the shiver might be interesting, for instance in its illustration of the connection between emotion and muscular movements. At all events we take this cloud, no bigger than a man's hand, as a symbol ; it is the external counterpart of the tear which comes sometime to all of us to blot out God's sun. Its shadow is Death's.

For in the midst of all the wealth and virility of life, all the bustle and gaiety of Summer days, he with the ever-harvesting sickle walks with swift feet. He mingles with the haymakers, and one is carried senseless off the field ; he troubles the waters of the seaside town, and the

ranks of the children who romped merrily on the sands are thinned; he passes among the flocks, and many need no more shepherding; he breathes among the dancing day-flies, and they sink with the setting sun. And why in the midst of life is there so much death, against which there is no standing or defiance even among the strongest? It is in part due to the fact that although the sunlight is the most powerful antagonist of the pestilence that walketh in darkness, to wit, the omnipotent disease-germs or Bacteria, the warmth and overflowing plenty of Summer days favour their fatal multiplications; as is illustrated by many fevers. It is partly because the machinery of life is by no means perfectly self-repairing, and that the organism in living is continually going into debt—death being the extreme of insolvency; as is illustrated by all organisms whose efforts are followed by irremediable nerve fatigue. And it is partly because during an early chapter in life's history immortality was pawned for love, and death was made a price for giving rise to new lives; as is illustrated by so many butterflies and other animals, not to speak of flowers, which die soon after reproducing.

But no one can have realised what the work of Summer actually means, without feeling that there is profound truth in the doctrine of reincarnations, that nothing is ever really lost in this economical world. Matter is ever circulating, in Summer most actively; energy is ever changing, in Summer most of all. Nothing is ever lost; all things flow. The moistened dust and the quivering air become the grass, the grass the deer, the deer the huntsman, the huntsman the tiger, the tiger—with the aid of Bacteria—grass again. For so the world goes round, and, "after last, returns the first, though a wide compass round be fetched."

SUMMER FLOWERS

WE have seen that the Biology of Summer has for its two main problems the manifold effect of heat and light upon living creatures, and the increasing preponderance of reproduction over nutrition, of flower over leaf, of "Love" over "Hunger." Heat, within limits, makes the wheels of life go more quickly round; it accelerates development and the lashing of cilia; it makes egg-cells twin, and it keeps the green flies parthenogenetic; and it has a hundred other influences. Light promotes assimilation in leaves and slows growth; it induces pigmentation and quickens our pulse; it makes Bacteria live so quickly that they die; and it has a hundred other influences. But our present study is concerned with the growing preponderance of flower over leaf.

Every one knows that a typical flower is made up of four different kinds of parts, arranged in circles or whorls, one within the other. Outermost are the sepals, making up the calyx; they are usually firm and green; they protect the bud and steady the opened flower. Next come the petals, making up the corolla; they are usually delicate and coloured, often fragrant, and often making nectar; they thus attract insect-visitors, and they are also useful in protecting the even more important parts farther in. The third whorl consists of the rod-like stamens, whose heads or anthers make the golden-yellow fertilising dust or pollen. The innermost parts of the fourth tier are the carpels, which bear microscopic eggs, each of which, if fertilised, will develop into

an embryo plant. Or, to put it in another way, the carpels bear *possible* seeds or ovules, which become *real* seeds when the fertilising golden dust penetrates into them.

It was a very important—unifying and clarifying—discovery, in which the poet Goethe had a large share, that the flower is really made up of four tiers of *leaves*, adapted to different uses—protective and steadying leaves, protective and attractive leaves, pollen-making leaves, and seed-making leaves. The different parts all grow out of the flower-stalk as leaves do, and they often hark back to their primary condition—for instance, when the plant is overfed. A Canterbury bell may become a crowded green tuft, and most "double" flowers are due to stamens becoming petaloid. Another argument (out of many) may be found in the flower of the water-lily, where the substantial green sepals pass quite gradually into white petals, and these narrow into straps, which pass into yellow stamens. In this flower and others like it we find it difficult to tell where sepals stop and petals begin, or where petals stop and stamens begin. In such ways we may convince ourselves that, though the four parts of the flower have different names and forms and uses, they have, fundamentally, a common nature, for they are all leaves, transformed in various ways and combining to fulfil the plant's chief end—that it should produce seeds which will bear next year's flowers. This was a discovery of the same nature as one of older date—that the forelimb of a frog, the paddle of a turtle, the wing of a bird, the flipper of a whale, the wing of a bat, and the arm of man, and so forth, are all fundamentally the same in essential structure and in mode of development; but the discovery of the nature of the flower was perhaps a greater illumination.

In one of the letters in *Fors Clavigera*, Ruskin commented somewhat savagely on the kind of botany that rejoiced in proving that there was "no such thing as a

flower" ; but further reflection lead him to see the significance of Goethe's thesis, and he then wrote a famous passage, which describes the nature of the flower in a beautiful way, combining inaccuracy and insight in a manner absolutely incomparable. "You will find," he said, "that, in fact, all plants are composed of essentially two parts—the leaf and the root—one loving the light, the other darkness; one liking to be clean, the other to be dirty; one liking to grow for the most part up, the other for the most part down; and each having faculties and purposes of its own. But the pure one which loves the light has, above all things, the purpose of being married to another leaf, and having child-leaves, and children's children of leaves, to make the earth fair for ever. And when the leaves marry they put on wedding-robes, and are more glorious than Solomon in all his glory, and they have feasts of honey, and we call them *flowers*."

In the great majority of cases the pollen is carried from one flower to another of the same kind by an insect intent on its own affairs—collecting nectar and pollen. As the dusting with pollen secures not only fertilisation, but cross-fertilisation, and as the latter is sometimes the only possible mode, and sometimes, at least, the most advantageous mode as far as the crop of seeds is concerned, we are not surprised to find that flowers exhibit numerous adaptations which attract insect-visitors of a profitable kind, and secure that the visits are made the most of.

Taking the simplest attraction first—that of nectar-production—we have no difficulty in recognising its naturalness. The plant is a sugar-factory; the leaves make enough and to spare; there is a surplus which oozes out as "a feast of honey." But an unregulated overflow would be obviously disadvantageous in attracting unwelcome guests, thus nectaries become floral, and their position in the flower is often finely strategic. When the fit and proper visitors have

come and gone, when pollination has been effected, when the season is getting on, then the nectaries close up, the feast is over, and the *fruit begins to fill.* We are aware that nectar is often more than sugar, that it may include balsam and gum, and so forth ; we are aware that a big book might be written about nectaries; but we are only concerned here in stating the general biological aspect of a very familiar fact—the flowers' feasts of honey.

The second accessory characteristic of the flower is fragrance, to which many insects are extremely susceptible. What is the primary significance of this incense, whose secondary advantageousness is so obvious ? The answer which suggests itself is that the fragrant substances are waste-products—in some cases by-products—of the essential metabolism that goes on in the plant. It will be remembered —we have only to think of woodruff and lavender and peppermint—that the fragrant substances often occur in leaves, though flowers have made a speciality of their production. The chemists have distinguished a great number of these aromatic compounds, such as the soporific aminoid in hawthorn ; the benzoloids in mignonette and violets ; the paraffinoids in valerian, pelargonium, and roses ; the turpenoids in orange and lavender ; the strange indoloids, said to arise from broken-up proteids, in aroids, Aristolochia, and Rafflesia which attract carrion-loving flies. There are said to be over five hundred of these aromatic compounds on the catalogue, and there are doubtless very many more. For different species, when they are worthy of the name, show individuality in their chemical processes as well as in structure and habit, and it seems not unlikely that we are as near the heart of the matter when we distinguish flowers by their fragrance as when we count the microscopic chromosomes in their nuclei. As with nectar-production, so with fragrance ; there are endless subtleties of adapta-

tion, one of the most familiar being that some flowers, such as Grass of Parnassus, give forth incense only in the sunshine, while others, like the Evening Campion, reserve this for the night.

After discussing the volatile ethereal oils to which the odours of plants are due, Professor S. H. Vines says: "With regard to the function and fate of these aromatic substances, it appears that they are of no use in the constructive processes; they are to be regarded as waste-products, destined, for the most part, to be thrown off. . . . We may venture upon the general statement that the higher plants, at least, cannot avail themselves of carbon when combined in an aromatic molecule for the purposes of their constructive metabolism. . . . Although the aromatic substances are probably to be regarded simply as waste-products, yet some of them are indirectly of use to the plant. We have seen that the odours of plants are due to the presence of volatile ethereal oils, and it has been ascertained that the odours of flowers serve to attract insects, and thus contribute to ensure fertilisation." [1]

The third accessory characteristic of the flower is its colour, which appears to be attractive to many of the insect-visitors. Let us consider the colour, first of all, in its internal or physiological aspects. It is due to a great variety of pigments, some of which are more intelligible than others. Some are fixed in protoplasmic corpuscles, notably those of a yellow, orange, brown (and rarely blue) colour. These are mostly derivatives of the leaf-green or chlorophyll, and the yellow anthoxanthin is a common example. The others are dissolved in the cell-sap, notably those of a white, violet, blue, red (and rarely yellow) colour. Most of these are derivatives of tannin and other bitter principles, and the blue anthocyanin is a common example.

[1] S. H. Vines, *Lectures on the Physiology of Plants*, Cambridge, 1886.

Our knowledge of pigments is still far from satisfactory, but there is considerable evidence that many of them are useless by-products in the economy of the plant. Thus Professor Vines says: "With regard to their chemical nature, the colouring matters of plants are considered to be closely connected with the aromatic group of substances. As to their physiological significance, they may be regarded simply as waste-products in so far as their direct use in constructive metabolism is concerned; but indirectly they are, in many cases, of great importance. Chorophyll is essential to the process of the formation of organic substance from carbon dioxide and water. The colours of flowers play an important part in attracting insects to visit the flower, and by this means cross-fertilisation is ensured."

It seems safer at present to avoid general formulation, for there are many indications, both among plants and animals, that pigments have very diverse meanings in the internal economy of the organism. Some are unimportant by-products, of little or no direct internal use after they are formed; others are very important by-products, of much direct internal use. Some seem to belong to the series of reserve-products, but most seem to be waste-products—the ashes of the vital fires. In some flowers the bright colouring means scanty local nutrition; in others, too rapid life; in some, too little moisture; in others, too much light; but in the majority it means *beauty for ashes.*

As to the general secondary significance of the colour of flowers, there is little doubt—it is attractive to insect-visitors This proposition may be upheld without insisting that all floral colour has this meaning, and without implying that the colour affects the insect's eye as it does ours. Grant Allen, in one of his brilliant essays, commits himself to the impetuous and eliptical statement: "Insects produce flowers; flowers produce insects. The colour-sense pro-

duces brilliant butterflies and brilliant beetles." Darwin went the length of saying: " If insects had never existed on the face of the earth, our plants would never have been decked with beautiful colours."

Let us state the thesis more fully. Although many flowers seem able to fall back on self-pollination, it is of advantage to most that insects should visit them. Those most visited are most certainly fertilised; they produce larger and more vigorous crops of seeds than those of the same kind which have been little visited. Long ago some of the primitive flowers began to form pigments as by-products or waste-products of their everyday metabolism. Those that varied in the direction of conspicuous or attractive coloration were most visited, therefore most effectively fertilised, and therefore most prolific in their multiplication. The uncoloured or dully coloured were less likely to be visited, and they would tend to go to the wall. In the case of each kind of flower that was visited by insects attracted by colour, there would thus tend to be a survival of the gay and an elimination of the dull. When we keep the insects in their proper place as the selectors of the variations which the plant afforded, the thesis appears more reasonable.

If we are convinced that pigments are natural expressions of the normal up-building and down-breaking of the plant, if we can find physiological reasons why they should occur (chloropyll apart) more particularly in connection with the flower, and if we do not find any reason for regarding conspicuousness of colouring as disadvantageous, then, it seems to us, we can keep insects in their place as selectors, and give flowers some credit for their own beauty.

In regard to the attractive power of floral colour, there is, to say the least, a need for cautiousness of statement. It has been repeatedly observed that bees do not seem to care much for yellow flowers, that they prefer blue-violet to any

other colour, that they frequent reds with a tinge of purple, but leave cinnabar reds alone. In such observations it is necessary to be very careful. A flower is a complex of stimuli, and the fact that blue-violet blossoms are most visited does not, in itself, prove that they are preferred because of their colour.

Sir John Lubbock, now Lord Avebury, tried to get away from the risk of fallacy by baiting different slips of paper of different colours with the same sugar, and the interesting and valuable result of his experiment was that the bees "preferred" the blues and violets to yellows, and so on. Even here, however, one must tread warily, since it seems likely that the bee has established associations—partly instinctive and partly based on previous experience, so that the stimulus of certain colours may act merely as the memorandum of previous good feeding. And, again, there seems good sense in Plateau's objection, that observations and experiments on this subject have not discriminated adequately between *colour* and *absolute intensity of illumination*. Those insects that love light choose the brightest surfaces; but brightness is one thing, and colour is another.

Plateau worked a good deal with dahlias, which are visited by humble-bees, butterflies, and other insects. His method was to hide the colour and form of the inflorescence by means of pieces of cardboard, which were variously coloured (white, black, green, etc.), or by means of green leaves. The results of his experiments led him to a heretical conclusion: "The form and the colour do not seem to have any attractive rôle; the insects are evidently guided to the capitula of the composites by some other sense than sight—probably by smell." Now, we do not believe that these and similar experiments have upset the theory that floral colour is one of the attractive stimuli which draws insects to the

flowers, but perhaps they may indicate the risk there is of exaggerating a truth till it becomes false.

In support of the generally accepted view that brightly coloured petals are attractive " signs " which draw customers to the floral " Gasthaus," there is a multitude of observations as to the frequency of visits paid by particular insects to particular flowers. It is instructive to give a holiday afternoon to watching, for instance, how one of the big humble-bees (*e.g. Bombus hortorum*) behaves on a flower-covered bank. She is so extraordinarily selective. And as we see this, it sends a thrill through us to remember that Aristotle watched the same sort of thing more than two thousand years ago. In his *Natural History* it is written : " A bee, on any one expedition, does not pass from one kind of plant to another, but confines itself to a single species—for instance, to violets—and does not change until it has first returned to the hive." After more than two thousand years, the botanist Kerner von Marilaun, who wrote one of the most living of all the botany books, watched not the hive-bee, but *Bombus montanus* in an Alpine valley. He saw it visiting only *Anthyllis alpestris*, and passing over *Pedicularis jacquini* and *P. incarnata* ; while in another valley the same species of bee buzzed from one *Pedicularis* blossom to another, and passed over the *Anthyllis* attractions.

We have now a perfectly precise and rapidly growing record of the habitual pollinators of particular flowers, and there has already been more than one good example of a truly biological (or œcological, if you like) student's " Flora," which tells for each plant, not only its diagnostic characters, but its welcome and unwelcome insect-visitors, its gall-producers (if it has any), its parasites, its seed-distributors (if it has any), its characteristic environment, and its plant associates. *In hoc signo laboremus.*

Corroborations come also from wide outlooks, in which

the exception often proves the rule. Thus Alfred Russel Wallace, still happily the Nestor of the evolutionist camp, pointed out long ago that there were few bright blossoms in the Galapagos Islands (600 miles west of South America), and that there were few insects. But in Juan Fernandez, 400 miles off Chili, there are several very conspicuous flowers, though there are no bees, only four moths, and one butterfly. There are, however, crowds of humming-birds, which are pollinators of high degree.

In studying a problem like the inter-relations of flowers and insects, it is necessary to pursue a rigorous analytic method, abstracting off first one factor and then another, inventing super-ingenious experiments to discover whether the bee comes to the blossom because the blossom is purple or because it is bright, because it is coloured or because it is fragrant, because it is fragrant or because it has lots of nectar, and so on. This is inevitable, and it is thus that science is built up. We have a lurking suspicion, however, that the scientific inquirer is apt sometimes to end in fallacy by projecting his analytic inlook upon Nature again. To return to a concrete case, we mean that a foxglove flower is a complex of stimuli, and that the bee which climbs up its spire is a complex of sensory receptivities. In all likelihood, the bee visits the foxglove on a bank and leaves out all others, not because the foxglove has a subtle pinkish-purple colour, but because it is a foxglove. It is the *tout-ensemble* that counts. But it is difficult, somehow, to make good science of this.

It would be unpardonable to quit the subject of summer flowers—even in these brief glimpses—without coming back to reality—the gorgeous pageant of Flora's Feast. The tide which sets in with a rush in Spring reaches its high-water mark in Midsummer. Play gives place to industry, and the extravagance of youth to the strenuous-

ness of maturity. The buds are replaced by hard-working leafy boughs with extraordinarily intense activity, especially in the sunlight. The bud-like, more primitive, early flowers are replaced by more liberal floral magnificence. On all sides we see young things passing through adolescence to mature strength, and love is crowned.

As a picturesque emblem of the fundamental fact—the rising wave of life—we may, in conclusion, allude to the observation of a remarkable scientific genius, Dr. Buchan, who has left a deep mark in the science of Meteorology, that of British plants which flower between April and July, the succession of colours tends *on an average* to be the order of the rainbow tints—from blue, through yellow, to red.

SUMMER INDUSTRIES

WE mean by industries those external activities which are concerned with the sustenance and care and development of life, or, in great part, with "production." They are *external* activities, which operate directly on the outer world, moving things about, changing matter and energy from one form to another, bringing them into more useful or, at any rate, more desirable shapes and arrangements. Thus neither the beating of the heart nor thinking can be called industries, though they are very important activities, and the latter is very fatiguing.

Industries, then, are concerned with getting hold of things and powers, transforming them, storing them, distributing them, and, in the case of man, exchanging them. The prime aim of industry, even though it be unconscious, is to sustain and develop life; its external result is always a product, or some change in the form, position, availability, or utility of a product. Thus war is not an industry, but weaving is; eating is not an industry, but hunting is; courting is not an industry, but keeping the home agoing is. So this biological study of industries does not even touch on a number of very interesting animal activities, such as wars and wanderings, courtships and plays.

A second and more difficult introductory note is necessary. The activities and industries of animals are at many different levels when considered from the point of view of the associated mental and nervous control. We

may arrange them on a staircase of five steps, or, better still, on a long inclined plane marked by five more or less clear divisions.

Lowest are those activities which go on without there being any nervous system involved. Such are the most important transformations of matter and energy that we know of in the whole world, namely, those that go on in green leaves, when, with the help of the sunlight shining through a screen of chlorophyll, they form complex substances like the starch of the potato and the gluten of wheat out of the simple elements of earth, water, and air. It cannot be called an industry in the strictest sense, since plants do not form products outside of themselves, but it may be taken as an example of vital activity that goes on without nervous control. We have no warrant for calling it anything but unconscious. There are many internal activities in animals on the same level; they go on independently of direct control from the central nervous system. It is well known that the turtle's heart will go on beating long after the bulk of the animal has been made into soup.

On a second level, there are simple reflex actions, which usually require the possession of a definite nervous system, but are not associated with what we call conscious control. The organism does not know that it does them, unless it happens to fix attention on their performance. We touch a hot iron, and without, in the strict sense, willing it, we draw our finger away. A stimulus has travelled up a sensory nerve to the spinal cord, and a stimulus has passed down a motor nerve to the muscles, commanding them to effective action. This is a reflex action of a simple kind, but there are many more elaborate activities and even parts of industries which appear to be compound reflexes. They are, as we say, automatic. If we may judge from

our own experience and from experiments made on animals, some of them seem not to be attended with any central consciousness at all, while of others it seems safer to say that they do not rise to the focus of consciousness.

On a third level are those activities which are called instinctive. By which is meant that they are performed in virtue of an inherited capacity; that they require no learning or experience, though they are usually improved by both; that they are shared alike by all members of the species, or, at least, by those of the same sex. Most animal industries must be included here, though there is sometimes a spice of intelligence intermingled in their performance. The spinning of spiders, the comb-building of bees, the paper-making of wasps, the agricultural industries of ants, and so on, seem to be, for the most part at least, instinctive. The animals are, so to speak, hereditarily wound up to do what they do. They are born with a ready-made power of doing certain things well. The difficulty is that some animals learn with great rapidity, so that it is often impossible without experiment to distinguish what is instinctive from what has been intelligently learnt. When a complex performance is gone through without a hitch the very first time it is attempted, and in the absence of any model, we may be fairly sure that it is instinctive, unless the performer has given other evidence of a high order of intelligence. Experiment may prove this, thus Professor Lloyd Morgan has been particularly successful in getting at pure instinct by his method of studying young birds hatched in an incubator and brought up in isolation.

On a fourth level are intelligent activities, which include some animal activities and parts of others. Here a higher note is struck. The animal is not only conscious, but controlling and contriving. It adapts old means to new ends, it profits by experience, it puts two and two together

in a simple way at least. We cannot redescribe these activities to ourselves without using psychological terms, without supposing that the animal draws inferences of some sort and thinks in the concrete at least. Thus when a spider departs from its beaten path to make a web adapted to entirely novel circumstances—for instance, to the wind on the seashore—when a bee mends its web in a fashion that we cannot help calling ingenious, when a monkey works a screwdriver, when an elephant helps to make a railway, and so on, we must allow at least a spice of intelligence, and often much more. There is room, of course, for much difference of opinion ; perhaps if the truth were known, for man to speak of "admitting" the intelligence of, say, an elephant or a collie is not far from the absurd. We have to steer between two extremes—on the one hand, of regarding animals as automatic machines of an amazing intricacy ; on the other hand, of reading the man into the beast. Because the hive-bee makes such beautiful hexagons, it is not to be spoken of as mathematical ; on the other hand, every naturalist must deprecate the arrogance of a recent pronouncement that men were brain-organisms and animals gut-organisms.

But there is a higher level still—that of rational activity ; and, so far as we know, we have this field all to ourselves. By rational, as distinguished from intelligent, is meant, that we cannot imagine the activities being carried out without general ideas, without conceptual inference as distinguished from perceptual inference, without thinking in the abstract. No one will suppose for a moment that man is always on this high level ; in fact, he is on it far too little, much of our industry, for instance, being in details non-rational and even non-intelligent. Nor dare we deny that some of the higher animals may show the beginnings of conceptual inference or of rational activity. From an

evolutionist point of view, this seems highly probable. All that we do say is, that there is no case of animal cleverness on record which may not be described without crediting the performer with general ideas—that is to say, all may be accounted for on the supposition that the activity is either instinctive or intelligent. Some lovers of animals think that we might be more generous when we are at it, but the scientific method holds fast by the law of parsimony, which forbids us making larger assumptions than are warranted by the facts.

The primitive human occupations of hunting, fishing, shepherding, and farming afford a convenient classification of a large group of animal industries—those concerned with food-getting.

Of the primary activity of hunting there are many modes. Lurking is illustrated by the crocodile at the water's edge, by the snake in the grass, by the octopus among the rocks ready to grapple a dreamy fish, by the larval ant-lion who digs in the sand a pitfall for unwary insects, and by a thousand more.

Others prowl about in search of their prey—the cats large and small treading noiselessly with claws of steel under their velvet gloves, the snakes gliding swiftly in the jungle like Kipling's famous Kaa, the foxes alone, the wolves in packs, the bats and owls and a hundred others by night, the eagles and swifts and a thousand others by day, the monkeys seeking out the orchards, the otter the trout-pools, the walrus the mussel-beds, some with wondrous swiftness like the weasel after the rabbit, others with great leisureliness like snails on the hunt for mushrooms. There is no end to the variety of ways and means.

Some of the details of device are full of interest. The thrush breaks the snails' shells against a stone, making heaps of the remains quaintly suggestive of the archæo-

logist's "kitchen-middens"; rooks sometimes let fresh-water mussels drop from a height on to the gravel, and it was thus that a Greek eagle killed the poet Æschylus by letting a tortoise drop on his bald head, which glistened like a white stone; the oyster-catcher knocks the limpet off the rock with a dexterous stroke of its strong bill; the grey shrike stakes its victims on thorns.

Of hunting by means of snares the best illustrations are of course afforded by spiders, of which one instance may be given, on the authority of Dr. Emil Goeldi, formerly Director of the Museum in Pará. It concerns an early rising spider, *Epeiroides bahiensis*, which was common in Goeldi's garden at Pará, though the web was never to be seen. The Director's son, a boy of seven, determined to sit up all night to solve the mystery, and he discovered a very interesting peculiarity. The spider makes its web in the early hours, but rolls it up and decamps with it after the sun rises. Penelope-like it destroys its web daily, but not without result to man as well as to itself, for it catches the minute-winged males of the destructive Coccus insects, of *Dorthesia americana* in particular. After retiring under the shade of a leaf, the spider investigates the insects in its rolled-up net, and spends the hot hours in digesting their juices. Its behaviour reminded Dr. Goeldi of a southern bird-catcher hastily gathering his roccolo together as the dawn breaks, but with this difference, that the spider "does not stop to pull out the captives, wring their necks, and throw them into a bag. It gathers up its net and postpones the work of revision until it gets home."

Fishing is only a variety of hunting, but may be considered separately for a moment. Typical of the patient angler, the heron stands by the pool-side—still as a statue, but able to strike with almost electric suddenness, or fly away with dignity if we disturb his fishing. But perhaps

HERON FISHING

(V)

we should have given first place to the angler—*Lophius piscatorius*—a fish who fishes, a fishing-frog he is often called. He is very inconspicuous as he lies squat on the sand in shallow water, and he is sometimes half covered with sand. Three elastic rods, one of them very strong, rise from the middle line of his back, and at the end of each there dangles a shred of skin like bait at the end of a fishing-line. These living fishing-rods are hinged at the base, so that they can be lowered or raised, and they are obviously transformed fin-rays. It is supposed by many that the shreds of skin, dangling loosely in the water, suggest worms to curious little fishes; it is supposed, at least, that they serve to attract attention; what is certain is that many small fishes are engulfed in the angler's wide gape, and gripped firmly by backward-bending hinged teeth which make entrance easy but exit difficult.

The tales of the fishing exploits of animals, like stories of fishing at a higher level, are often a little difficult to believe. The deep-sea fish *Chiasmodon niger* has been known to swallow a fish larger than itself; a large spider has been known to land a small fish; the archer fish, *Toxotes jaculator*, is said to make its living by shooting drops of water, with Transatlantic precision, on passing insects. But perhaps more instructive than such oddities is the habit pelicans have of fishing in company, and wading shorewards in a deadly crescent, prophetic of the seine-net. Clumsy birds they are, but exhibiting a remarkable power of co-operative industry, if reports are true. We venture to quote Kropotkin's account:[1] "They always go fishing in numerous bands, and after having chosen an appropriate bay, they form a wide half-circle in face of the shore, and narrow it by paddling towards the shore, catching all fish that happen to be enclosed in the circle. On narrow rivers and canals they

[1] Mutual Aid, 1902.

even divide into two parties, each of which draws up on a half-circle, and both paddle to meet each other, just as if two parties of men, dragging two long nets, should advance to capture all fish taken between the nets when both parties come to meet. As the night comes they fly to their resting-places,—always the same for each flock,—and no one has ever seen them fighting for the possession of either the bay or the resting-place. In South America they gather in flocks of from forty to fifty thousand individuals; some enjoy sleep while the others keep watch, and others again go fishing."

Of shepherding, the only clear illustrations are to be found among ants, some of which (e.g. *Lasius niger* and *Lasius brunneus*) keep aphides or green-flies, and others scale-insects. This extraordinary habit was well known to Linnæus, who called the aphides the ants' cows (*vaccæ formicarum*), and it has received considerable attention from many observers. Perhaps it began in the simple fact that the ants and the aphides frequented the same trees, dining, as it were, at the same bountiful table. Then it was discovered that the aphides would yield up some of their "honey-dew" when licked or tickled, and the ants traded on this. Gradually, perhaps, the ants began to take some charge of their cattle, even building "aerial stables" for them on the branches. The ants are accustomed to put their pupæ out to be sunned, and to carry them back again when it rains; perhaps this habit led on to what at first sight is so startling, that the ants take aphides down into their underground nests. "In Autumn the aphides lay eggs in the cellars to which they have been brought by force or coaxing or otherwise, and these eggs the ants take care of, putting them in safe cradles, and licking them as tenderly as they do their own." It is probable that this very interesting habit arose neither deliberately nor casually, but by the gradual extension of habits previously established; and

it must be remembered that ants and termites are remarkable for their friendly associations with other insects, which they tolerate in their nests, sometimes as useful inmates, oftener apparently just as pets.

What we have just referred to recalls what Edward Jacobson has recently reported regarding a mosquito which seems to milk ants! For that is what it comes to. The mosquito frequents certain trees in Java, on which the ants in question (*Cremastogaster difformis*) go to and fro. It hails a passing ant and strokes the head with quick movements of its forelegs and antennæ, probably tickling, perhaps massaging, the ant. In any case, the ant emits a drop of juice, which the mosquito, sucks up. Then the ant goes on its way, a pathetic instance of naturally good abilities, spoilt by an exaggerated state-socialism. The gentle mosquito has been named *Harpagomyia splendens* by de Meijere, who points out that the creature cannot bite! Jacobson found two other Diptera in Java which seem also to have learned how to tap ants. Like the mosquito, they have discovered a deep wisdom in the old advice—"Go to the ant, thou sluggard."

Agricultural industries are again illustrated among the ants. The harvesting of grain, believed in from ancient days, but challenged by careful entomologists such as Latreille, Huber, and Kirkby, has been satisfactorily described by Moggridge and others. In his *Agricultural Ant of Texas*, M'Cook gave an account of the abundant red-bearded ant (*Pogonomyrmex barbatus*), which weeds out circular discs in open ground, tolerating only the needle-grass (*Aristida*), whose seeds are gathered and stored along with others in underground granaries. "Not a plant is allowed to intrude upon the formicary bounds; and, although often seen, it was an interesting sight, after pushing through the high weeds, to come upon one of these nests, and observe the

tall, tough vegetation standing in a well-nigh perfect circle around the edge of the clearing. The weeds had crowded up as closely as they dared, and were held back from the forbidden grounds by the insects, whose energy and skill could easily limit their bounds. Certainly, ants capable of such work could readily have cleared away growing stalks of the Aristida. In fact, after the seed has ripened in the late summer, they are said to clear away the dry stalks in order to make way for a new crop. It is this that justifies the reputation of Barbatus as a farmer. She has not been seen—so far as the author knows—sowing the seeds, but she permits them to grow upon her formicary bounds, and afterwards utilises the product." [1]

In a recent careful study of *Messor barbatus*, a leaf-cutting and seed-gathering ant of Dalmatia, Professor F. W. Neger of Tharandt noted that most of the seeds (of Leguminosæ in particular) were allowed to begin to germinate before the ants put them out to dry. This seems discrepant with what is often stated, that ants treat the seeds in such a way that they cannot sprout. But Neger suggests that the germination permitted has the advantage of bursting the seed-coats. It is then stopped by exposure, so that it does not go far enough to ferment the starch into maltose and dextrin. When the seeds are thoroughly dry and dead, they are taken back again to the nest and chewed into a dough. This is baked in the sun into minute biscuits, which are stored. Here, in fact, we have an industry that comes very near to cooking.

One of the most extraordinary habits of the termites or white-ants, so abundant in warm countries, is that about thirty different species feed on moulds which are grown within the termitary on specially constructed maze-like beds of chewed wood. The fungi are believed to afford a supply

[1] H. C. M'Cook, *Nature's Craftsmen*, 1907.

of nitrogenous material which is scarce in the termite's ordinary diet of wood. It is interesting that a similar habit of growing moulds occurs in some of the true ants which belong to quite a different order of insects. And a similarly puzzling convergence is illustrated by the fact that termites, like true ants, often have boarders in their hills, mostly small beetles, neither hostile intruders nor parasites, but guests which are fed and cared for apparently on account of a palatable exudation, with a pleasant narcotising effect on the termites !

Many animals, besides ants, illustrate storing, either for themselves or for their offspring. We need not here do more than mention squirrels and beavers, hive-bees and scarabees, for we shall return to storing in its more appropriate seasonal setting as an autumnal industry.

After the primitive industry of securing food, which has so many forms, may be ranked that of making shelters, including clothes. Although Carlyle and others have pointed out that man is the only clothed animal, the point is debateable. It is difficult not to regard as clothing the cocoon of a silk-worm or the case of a caddis-fly, and there are crabs which fix seaweeds on to their backs, or cut off the tunic of a sea-squirt and use it as a cloak.

Of making shelters there is an embarrassing wealth of illustration. They are often hollowed out in earth and wood, and vary from rough burrows like a rabbit's, to a beautifully finished structure like the tube of the female trap-door spider, with its hinged door and its side-room with a curtain over the entrance. Or they may be made of light materials, woven or sewn or somehow fastened together, one of the most striking types being the decorated bower of the bower-bird, since it is a house rather than a cradle, as most nests are. Or they may be genuine buildings of clay or other material. At one end we may place the substantial termi-

tary, sometimes ten feet high and strong enough for a man to stand on; at the other end the dainty nest of the wasp, almost as light as a feather.

Let us take one instance of the manner of working—the behaviour of the tailor-ant, *Oecophylla smaragdina*, common in hot countries. One must confess to a feeling of relief at finding recent circumstantial confirmation of some of the extraordinary tales that have been told of this creature. Professor E. Bugnion has recently vouched for the habit these ants have of using their silk-secreting larvæ as needle and thread when they are binding leaves together to make a nest! They sometimes find it difficult to bring two rather distant leaves close enough together to be sewn. Bugnion confirms the tale that five or six will form a living chain to bridge the gap. The waist of A is gripped in the mandibles of B, who is in turn gripped by C, and so on—a literally living chain, a notable gymnastic feat. Several chains will work together for hours on end trying to draw two leaves close together.

Even this brief study may serve to suggest a number of general reflections. The first is simple enough, that these industries of animals play a fundamental part in the business of the earth. This is evident when we think of the bees that fertilise the flowers, or of the earthworms that make the soil, or of the coral polyps that build up islands, and so on, till one may count a thousand. Secondly, although we are far from confident as to the psychological interpretation of many of the activities, the fact is plain that they are usually extremely effective in their performance and beautiful in their result. Thirdly, although we must be careful in applying to animals terms rich in ethical content, such as altruistic, the fact is plain that great labour is often expended for others—for the offspring—which the toilers in not a few cases never survive to see.

COURTSHIP OF BIRDS

IN most birds the amatory period is sharply punctuated. Their love is seasonal and part of the Spring. It becomes parental, laps the family in its folds, and then it seems to wane away into little more than kin-feeling, except in those birds that are monogamous and lifelong companions.

Partly, perhaps, because the time of ardent love is so sharply punctuated, the seasonal expression of it is more striking than in most other creatures. We see love condensed, so that for a time it sublimes the whole life. The mood changes, the feathers change, the voice changes, the very movements change, under the pervasive influence of love.

Many male birds acquire their special characteristics of colour and plumage, of song and flight, only as they approach the crest of the wave of adolescence, and some only retain their full glory while the love-impulse lasts. Some cock-birds put on long plumes, feathery tresses, brightly coloured combs and wattles, top-knots and curious markings, which they display before their desired mates with what seem to us, from a considerable *mental* distance, like emotions of love and vanity. Others vie with their rivals in fierce tournaments, and many try to sing their neighbours down. Some indulge in quaint strutting dances, and others in elaborate displays of their flying powers. Especially on the male side there is an exaltation of the whole life—physical as well as psychical.

The whole subject of preferential mating among animals

is full of difficulties, and though birds have been so much studied, there is still great uncertainty as to the significance of their behaviour. It seems as though this must remain until ingenious experiments are devised to test the inferences from observation.

Every one recognises that the advent of the pairing season is marked by a variety of unusual activities on the part of male birds—activities of song and flight, of dance and display, which seem to express excited states of feeling and to prompt similar responses on the female's part. We may sum up the characteristic activities in the word "courtship," though there are few data which would enable us to decide how far there is deliberate wooing on the one hand or deliberate choice on the other.

Sex-Dimorphism

No one without a microscope can tell a male sea-urchin from a female sea-urchin, and in the lower reaches of the animal kingdom an external uniformity of the two sexes is very common. As we ascend the series, however, differences between the sexes become more and more frequent and conspicuous. The essential functions of the males and the females become more and more different, as we may see if we contrast starfish with fish, or fish with mammal; their habits of life diverge; and to the primary differences there are added all manner of secondary peculiarities. In the higher reaches of the animal kingdom we come face to face with marked "sex-dimorphism," familiar in the contrasts of peacock and peahen, ruff and reeve, stag and hind, lion and lioness. In the contrast of man and woman the dimorphism finds its highest and subtlest expression.

As to the biological significance of this sex-dimorphism there is much difference of opinion, and we can only hint at

one of the lines of interpretation. There is much to be said for the view that there is a deep constitutional difference between the male and the female organism—an initial or germinal difference in the balance of chemical changes. The female seems to be relatively more constructive, relatively less disruptive. There is a fundamental difference in what we call figuratively the protoplasmic rhythm—the physiological gearing. This initial difference leads to the primary functional distinction between male and female. But it also determines, either from the start, or after maleness and femaleness have been in part established, what particular expression will be given to a whole series of minor characters—both structural and functional—whether a masculine or a feminine expression. It is convenient to keep the terms maleness and femaleness for the primary functional distinction—the male salmon depositing the fertilising milt upon the eggs which are liberated from the roe or ovary of the female salmon; and to keep the terms masculine and feminine for the contrasted expression that analogous characters find in the two sexes.

We cannot here do more than indicate the nature of the evidence in support of the view that a deep, initial, constitutional difference expresses itself primarily in what we call maleness or femaleness, and is also decisive, late or early, directly or indirectly, in determining whether detailed characters will find a masculine or a feminine expression. One egg becomes a cock, another egg a hen; but no microscopic differences are detectable; and no one yet knows what gives the egg a bias towards maleness or femaleness. In the higher animals at least the divergence is initial, and in a short time it finds visible expression. The developing creature gets on to definitely male or female lines, and the getting on to

male or female lines of development determines sooner or later whether the detailed characters take a masculine or a feminine expression. In some cases, probably, the initial constitutional difference is itself continued on in the building up of every part, deciding, as it were, at point after point, whether the hereditary characters will express themselves in the masculine or in the feminine mode. In other cases, certainly, it is the saturating influence of the early established maleness or femaleness that determines the masculine or feminine development of detailed parts, and of habits as well as structure.

What is the nature of the evidence that might be adduced to illustrate the saturating influence of the primary maleness or femaleness, as the case may be? It is indirect rather than demonstrative. The sex-dimorphism is pervasive, it goes through and through. As Havelock Ellis says: "A man is a man to his very thumbs, and a woman a woman to her little toes." The difference can be read in the blood—so safe and subtle an index to what goes on throughout the body. The difference can be read throughout life—it is seen, for instance, in the baby boy and baby girl, it is expressed in old age. It is seen even in the different ways in which the two sexes take the same disease.

Of more technical evidence we give only one illustration. A spae'd pullet may acquire not only the outward structural features of the opposite sex—cock's comb, wattles, long hackle and tail feathers, rapidly developing spurs, carriage, etc., but the behaviour as well, and the pugnacious disposition!

It is very important, we think, to realise that masculinity and femininity differ greatly in their accentuation. There is no such contrast in the sexes of starfish, but it is obtrusive in turkeys. And just as there are individual

organisms in which the masculinity or femininity is below par when compared with what is normal for the race in question, so there are species in which the males are relatively feminine and the females relatively masculine, judging by what is seen in related species.

In the majority of birds which show sex-dimorphism the males are distinctly the handsomer and more decorative. They are keyed to a different pitch of artistic excellence. Not that we would disparage any female bird; we only mean that they are on another line. The males are more luxuriant, exuberant, and elaborate. A cock chaffinch is one masterpiece, the hen chaffinch is another.

Some of the exceptions are interesting, but difficult to understand. In the Hemipods, or Bustard-quails, small quail-like birds about the size of sparrows which inhabit Africa, India, China, Burmah, Malay, and Australia, the female is usually more brightly coloured than the male, and also larger. "The male is a very plain-plumaged little fellow, but the female towers above him in size, and has often a black throat or a rufous collar as a distinguishing character." The apparently older species have the sexes alike, so in this case it seems that the evolution of decorativeness has been on the female side. Now it is very interesting to notice that in these bustard-quails, in which the females are the larger and handsomer, only the females call and only the females fight. The males sit upon the eggs, while the females roam about, "calling and fighting, without any care for their obedient mates; the males, and the males only, tend the young, and are to be flushed along with the brood." "After having deposited her three or four eggs in an apology for a nest, the female leaves the incubation and rearing of the young to be performed by her husband, weak little man that he is, while she roams about, seeking for some equally strong-minded lady to fight

with." The study of these exceptional cases is very interesting in connection with the theory of sex. Most snipes and sandpipers, Bowdler Sharpe notes, show a superiority in the female sex, but usually in size alone. In the African and Indian forms of Painted Snipe (*Rostratula*) the females are brighter as well as larger. Among birds of prey the female is often the larger and more powerful bird, but there is little decorative difference.

One of the most striking of the exceptional cases is the Red-necked Phalarope (*Phalarope hyperboreus*), a graceful fairy-like bird that breeds on the Arctic shore. The female is a perfect female, but she is very masculine in several ways, and is much more richly coloured than her mate. The male is a perfect male, but he is very feminine in some of his ways. We quote an account of their behaviour.

Mr. E. W. Nelson writes:—"The dull-coloured male moves about the pool apparently heedless of the surrounding females. Such stoical indifference usually appears too much for the feelings of some of the fair ones to bear. A female coyly glides close to him, and bows her head in pretty submissiveness, but he turns away, pecks at a bit of food, and moves off; she follows, and he quickens his speed, but in vain; he is her choice, and she proudly arches her neck, and in many circles passes and repasses close before the harassed bachelor. He turns his breast first to one side, then to the other, as though to escape, but there is his gentle wooer ever pressing her suit before him. Frequently he takes flight to another part of the pool, all to no purpose. If, with affected indifference, he tries to feed, she swims along side by side, almost touching him, and at intervals rises on wing above him, and, poised a foot or two over his back, makes a half-dozen quick, sharp wing-strokes, producing a series of sharp, whistling noises in rapid succession. In the course of time,

it is said, water will wear the hardest rock, and it is certain that time and importunity have their full effect upon the male Phalarope, and soon all are comfortably married. The captive male is introduced to new duties, and spends half his time on the eggs, while the female keeps about the pool close by."

Modes of Courtship

Let us select a few illustrations of different modes of courtship among birds. Perhaps the first place must be given to song, but this raises so many questions that it must be dealt with separately. It must suffice here to refer to its variety, and one of Brehm's sentences will serve. "Dominated by love, the jay sings, whistles, and murmurs, the magpie chatters, the croaking raven transforms his rough sounds into gentle, soft notes, the usually silent grebe lets its voice be heard, the diver sings its wild yet tuneful ocean-song, the bittern dips its bill under water that the only cry at its command may become a dull, far-sounding booming." And what is one to say of the nightingale, the mavis, the blackbird, the lark, the bullfinch, and so through the long list of the Spring orchestra? In some cases there is a certain degree of instrumental music, for it has been shown that the drumming or bleating of the snipe is due to the bird's rapid passage through the air with the outer tail-feathers held very tensely.

Secondly, there is all the glamour of graceful movement. Birds of prey ascend to giddy heights, let themselves go, almost touch earth, and are up again—circling, soaring, hovering. The flight of the eagle-like bateleur of the interior of Africa is marvellous at all times, but at the pairing time it becomes "an incomparable mountebank

performance in the air, a bewildering acrobatic display, which seems to unite in itself all the arts of flight practised by the other birds of prey." So it is with hundreds of birds: emotion finds expression in motion; swallow and lark, dove and pipit, bee-eater and bunting—all have their wonderful aerial displays.

Some that have no display of flying powers show off on foot. Cocks strut, turkeys dance, cranes pirouette to the verge of exhaustion, and even the solemn stork has its minuet. The capercaillie and the black grouse, the pheasant and the peacock, are among the famous dancers. Even the phlegmatic albatross indulges in antics, and the tragopan goes in for the most extraordinary posturing and posing.

A third aspect of the courting is seen in the combats of rival males. It is an unforgettable experience to get up before dawn in the Spring, to creep quietly up the hillside and hide in a sheep-fold, thence to spy on the "lek" of the polygamous Black Grouse. The cocks strut and fight on the level sward near by; the hens stand looking on, like the dames at a tournament. The cock utters a peculiar indescribable note, he spreads and depresses his highly decorative tail, and indulges in extraordinary antics, often ending with an excited charge on his rivals. When the spectacle is at its height and the rising sun strikes the combatants, it is difficult to believe that we are looking at the familiar Black Grouse, so remarkable is the transfiguration. In the end the most successful cock flies off with a following of fascinated hens.

There are hundreds of other cases, though none more picturesque, of combat and parade. Self-assertiveness runs riot. Love flames out luridly into jealousy. Every one will be cock of the walk, and hence the fray. The biological interest of a cock-fight is in its illustration of masculine self-assertiveness becoming almost maniacal.

Capercaillies fight till the snow is sometimes red with their blood, and their tournament is associated with a not less excited parade. The variable ruffs, which used to breed abundantly in the marshy parts of England, but are now little more than non-nesting visitors, illustrate combativeness carried almost to a pitch of absurdity. At the pairing time they assemble in companies to joust, and they sometimes fight almost the whole day. In spite of all the fuss and flurry, however, the exuberant combat ends, like many a duel, without the rivals doing one another much harm.

In many cases it is far otherwise. The little swifts and the great eagles sometimes fight to the death, and the same may be true of ostriches and swans, storks and chaffinches, and many other birds. The spur-winged plovers and spur-winged geese are savage fighters. Weismann and Bordage have called attention to the very interesting biological fact that in some habitual fighters, like storks and game-cocks, there is a remarkable regenerative capacity in the bill. Large pieces of the bone as well as of the horn sheath may be regrown after injury—a very unusual circumstance, for in creatures high up in the scale of being the "regenerative capacity" is usually very slight.

We quote a paragraph from A. E. Brehm to illustrate further the wealth of variety in "courtship."

"The means by which a male bird declares his love and conducts his courtship are very various, but, naturally, they always accord with his most prominent gifts. One woos with his song, another with his wings, this one with his bill, and that with his foot; one displays all the magnificence of his plumage, another some special decoration, and a third some otherwise unused accomplishment. Serious birds indulge in play and joke and dignified pranks, silent ones chatter, quiet ones become restless, gentle ones combative, timid ones bold, cautious ones careless; in short, all show

themselves in an unwonted light. Their whole nature appears changed, for all their movements are more active, more excited than usual, and their conduct differs from their ordinary behaviour in every respect ; they are possessed by an intoxication which increases the elasticity of their nature to such a degree that no flagging is ever perceptible. They deprive themselves of sleep, or reduce it to a minimum without weariness, and while awake they exert all their powers to the utmost without fatigue."

It is all like a prototype and at the same time a caricature of human wooing.

Theory of Preferential Mating

Darwin believed that the female birds exercised a real choice, yielding themselves to those cocks that pleased them most. He also believed that the choice was definitely based upon particular excellences of the chosen mates—fineness of song, exuberance of plumage, agility in flight, winsomeness of dance, or impressiveness in parade. He gave the hen-birds credit for æsthetic preferences, and his general theory was that by persistently selecting the males who varied in the direction of finer song and brighter plumage, they had gradually evolved these qualities to a high pitch of perfection. "The females," he said, "have, by a long selection of the more attractive males, added to their beauty and other attractive qualities. If man can in a short time give elegant carriage and beauty to his bantams, according to his standard of beauty, I can see no reason to doubt that female birds, by selecting during thousands of generations the most melodious or beautiful males, according to their standard of beauty, might produce a marked effect." In short, constitutional variations are common, and a variation very advantageous to its possessor in courtship runs a fair

chance of being established and of being perfected by the success it entails. Sexual Selection is thus only a special case of Natural Selection, with this difference, that the female bird takes the place of the general environment in picking and choosing what is fit, or in leaving out what is relatively unfit.

Darwin's illustrious collaborateur, Alfred Russel Wallace, has taken a different view of the facts. Attaching little importance to the alleged Sexual Selection, he interprets the sex dimorphism in terms of Natural Selection. Conspicuousness during incubation is dangerous. The more conspicuous females are picked off the nest by hawks, foxes, and the like, and hence only sober-coloured females remain. According to Darwin, the gayness of male birds is due to Sexual Selection on the part of the females ; according to Wallace, the plainness of the female birds is due to Natural Selection, which has eliminated those that persisted to the death in their gay plumage. Darwin starts from uniform sexes, and accounts for the gorgeous males by Sexual Selection ; Wallace starts from uniform sexes, and accounts for the sober-coloured females by Natural Selection. In 1773, the Hon. Daines Barrington, a naturalist still remembered as the correspondent of Gilbert White, suggested that singing-birds were small and the hen-birds mute for safety's sake. This is in principle the same idea as that which Wallace has elaborated.

It is quite possible that there is truth on both sides, for Sexual Selection might in some cases act as an accelerant of the evolution of bright plumage, while Natural Selection might in other cases have a retarding influence when conspicuousness was dangerous. The difficulty is to get at the facts. We have not sufficient data to answer the crucial question whether a considerable number of males are left out in the cold unmated, and, if so, whether they are appreciably

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inferior in attractiveness or in stimulating power. If this is not the case, the process of Sexual Selection does not work.

It seems very important that we should get to know more in regard to the correlation of the masculine or the feminine characters. There is a growing body of evidence to show that the secondary differences between males and females hang together physiologically, and that a condition of their development in the individual is an internal liberating stimulus from the essential reproductive organs. The secondary sex peculiarities, which we may sum up as masculinity or femininity, are the manifold outcrops of the deep primary constitutional difference which leads to maleness or to femaleness, which makes of one animal an egg-producer and of another a sperm-producer. A study of the hereditary relation throughout the world of organisms leads to the idea that every germ has a dual inheritance of masculine and of feminine characteristics. One or other of these will find expression in development, according as the germ develops towards maleness or femaleness. What determines the sex is a still more difficult question.

Another useful idea has become clearer of late. It is now generally believed that what the female chooses—if she chooses—is not so much slight improvements in chirping or song, slight excellences in colour or scent, but rather the *tout-ensemble* of that male who most excites her sexual interest.

As Weismann says: " Even though we certainly cannot assume that the females exercise a conscious choice of the handsomest male, and deliberate, like judges in a Court of Justice, over the perfections of their wooers, we have no reason to doubt that distinctive forms (decorative feathers and colours) have a particularly exciting effect upon the female, just as certain odours have among animals of so many different groups, including the butterflies."

Though Darwin sometimes seems to credit the female with no small degree of æsthetic fastidiousness, he also states that "it is not probable that she consciously deliberates; but she is most excited or attracted by the most beautiful, or melodious, or gallant males."

Lloyd Morgan puts the modern view tersely when he says: "The most vigorous, defiant, and mettlesome male is preferred, just because he alone affords a contributory stimulation adequate to evoke the pairing impulse, with its attendant emotional tone."

THE SONG OF BIRDS

IT is interesting to remember, when all the land is full of song, that for many millions of years there was no living voice upon the earth. Living creatures in abundance, but all voiceless—such was the state of things until the time of the Coal Measures, when amphibians appeared, presumably with vocal cords as frogs and toads have to-day. It is true that long before that there were insects, some of which were perhaps able to chirp and hum as crickets and bees do now, but this is rather instrumental than vocal sound-production. In any case, apart from insects, there was for millions of years no sound to break the silence of Nature—save the inanimate noises of the waves and the cataract, the thunder and the wind.

The invention of speech seems to have been due to the amphibians, but they did not make much of it, and few of their successors, the reptiles, made more. The snakes, for instance, have no word but a hiss, and most of the reptiles make no sound at all. Among birds, however, as every one knows, vocal expression attains to a remarkable degree of evolution, surpassed by man only, who has informed it with reason. To keep our ideas clear, it must be recognised that many birds and mammals have definite *words*, indicative of particular things or expressive of definite emotions; but song and language mean something more. In language, of which man seems to have a monopoly, there must be, if it is worthy of the name, the expression of a judgment—a sentence, however simple. In song there is rhythmic, modulated

reiteration, whose significance is emotional, not informative. It is idle, indeed, to pretend that hard and fast definitions can be given—that is a pre-Darwinian demand—for there are many approximations to song whose inclusion or exclusion within the rubric must remain a matter of opinion. The long-drawn-out, modulated pairing-call of many of the waders, such as the redshank, is on the border-line, and there are many who would call the reiterated call of the cuckoo a stammering song of the simplest sort.

Professor Alfred Newton writes in this connection: "It is necessary in a scientific spirit to regard every sound made by a bird under the all-powerful influence of love or lust as a 'Song.' It seems impossible to draw any but an arbitrary line between the deep booming of the emeu, the harsh cry of the guillemot (which, proceeding from a thousand throats, strikes the distant ear in a confused murmur like the roar of a tumultuous crowd), the plaintive wail of the lapwing, the melodious whistle of the widgeon, 'the cock's shrill clarion,' the cuckoo's 'wandering voice,' the scream of the eagle, the hoot of the owl, the solemn chime of the bellbird, the whip-cracking of the manakin, the chaffinch's joyous burst, or the hoarse croak of the raven, on the one hand, and the bleating of the snipe or the drumming of the ruffed grouse, on the other. Innumerable are the forms which such utterances take." It seems to us, however, that, while there are no hard and fast lines, it is possible and useful to distinguish between a simple love-call and a modulated, reiterated "song." That none of them are "songs" in the strict musical sense is admitted on all hands.

The true singing-birds belong to the huge order of Perchers or Passerines, which includes over six thousand species, and has a practically world-wide representation. But it is especially in the North Temperate region that song

finds its highest expression, and perhaps there is no region so highly favoured as Middle Europe, with its nightingale and bullfinch, its blackbird and thrush, its lark and wren. North America is not far behind with its bobolink and bluebird. It must be admitted that there are good singers in many parts of the tropics, but they do not attain the dominance characteristic of those in the North, and their songs are apt to be drowned in the shrill screams of their neighbours. In some warm countries, such as Brazil, the evolution of bird-song seems to have lagged far behind the evolution of gorgeous plumage—one of the general facts which suggest the familiar interpretation of song as a factor in preferential mating.

In mammals, the seat of the voice is in the larynx, at the top of the windpipe; in birds, the vocal cords are not in the larynx, but in a special song-box or syrinx at the foot of the windpipe, where it divides into the two bronchial tubes. Let us consider the mechanism very briefly. Three parts have to be distinguished. There is the framework of bone, consisting of several pieces, more or less movable in relation to one another. There is the external musculature, moving the parts of the framework and controlled by a rather complex innervation (implicating the twelfth cranial nerve, the first cervical from the spinal cord, and the sympathetic system in the neck). Thirdly, there are vibrating membranes and elastic folds, which are kept in varied degrees of tension by the action of the muscles, so that various notes are produced by the air driven out from the lungs.

It is of interest to note that the voice-box is most complex in Passerine birds, and that within the wide limits of this order there are many grades of differentiation, especially in the masculature. Even among the true songsters (the Passeres Oscines) there are many grades of

complexity, but Professor Valentin Häcker,[1] who has given special attention to the subject, points out that it is not possible to establish a close parallelism between the complexity of the muscular apparatus and the melodiousness of the song. Thus the syrinx-musculature of the thrushes (Turdidæ) is in some respects less evolved than that of the crows (Corvidæ). As Häcker says, much must depend on the differences in mental aptitude, temperament, and musical taste in the various types.

It is well known that the males are almost always better singers than their mates. Indeed, some females do not sing at all. Häcker's comparison of the vocal mechanism in the two sexes leads him to the general conclusion that the female syrinx is marked by smaller size, weaker musculature, a more primitive skeletal architecture, and less evolved vocal cords. It remains at a slightly lower grade of evolution. But although the structural differences may account for differences in the strength and volume of the voice, they do not explain the not infrequent difference in the actual character of the song. This must depend on mental differences in the two sexes.

For a few birds, such as the lapwing, it has been proved that the capacity for uttering the characteristic call is inborn. It depends in part on the particular peculiarities of the vocal mechanism and in part on cerebral endowments. Professor Häcker points out that birds belonging to the same genus, but to different species, have often certain combinations of notes in common, and he refers also to the fact that a young blackbird in his first year will sing a generalised thrush-song, which is not nearly such a fine thing as a blackbird's. It is much to be desired that careful experiments should be made to give us more precise information as to what a bird can or

[1] *Der Gesang der Vögel*, Jena, 1900, p. 19.

cannot do in the way of song when it is isolated from its kin.

Although there is considerable uncertainty, it seems as if the *general character* of the voice and of the call was hereditarily determined, while the actual melody is acquired by education. Imitation plays an all-important part, and thus much depends on those who serve as models. "In places where nightingales enjoy protection from cats and other persecutors, there are naturally some very old birds, who improve their melodies from year to year, both as regards purity and strength of notes, and thus become more and more efficient teachers of youth. In such circumstances the nightingale's song acquires a fineness and gradually increasing perfection, while in other districts, where the birds never live long, the general level of musical culture is low."

Indirect evidence of the importance of imitation is afforded by the well-known fact that many birds readily pick up snatches of song from other birds, stealing one another's music. According to Witchell, skylarks reproduce the cries or songs of yellow bunting, tree-pipit, swallow, blackbird, martin, house-sparrow, chaffinch, peewit, wagtail, hedge-accentor, and so on; but when he goes on to include the "sheep's bleat," we must confess to a strain on our faith. He says, however: "The 'sheep's bleat' above mentioned is difficult to identify in so musical a voice as that of the skylark; it is a short but distinct sound, only to be described in the word *baa*."

Another fact of fundamental importance in regard to bird-song is its *primary* connection with mating. It has its roots in love-calls uttered by the excited male, and producing excitement in the coy female. We must return to the theory, but it is important first to note the fact that song wanes away or abruptly stops as the pairing season

DIPPER ON A STREAM

(VI)

passes. "Almost coinstantaneously with the hatching of the nightingale's brood, the song of the sire is hushed, and the notes to which we have for weeks hearkened with rapt admiration are changed to a guttural croak, expressive of alarm and anxiety, inspiring a sentiment of the most opposite character. No greater contrast can be imagined, and no instance can be cited which more completely points out the purpose which song fulfils in the economy of the bird; for if the nightingale's nest at this early time be destroyed or its contents removed, the cock speedily recovers his voice, and his favourite haunts again resound to his bewitching strains. For them his mate is content again to undergo the wearisome round of nest-building and incubation. But should some days elapse before disaster befalls their callow care, his constitution undergoes a change, and no second attempt to rear a family is made." [1]

As to the theoretical interpretation of bird-song, various suggestions have been made. The Darwinian view regards the male bird's power of song as an asset in the business of courtship. The best singers were most successful in wooing, and thus the musical talent was improved generation after generation. It is not necessary to suppose that improvement always implied a structural change in the song-box mechanism; for, while that doubtless went on, what was mostly selected was probably a certain type of constitution—an attractive fellow, in short. Nor is it necessary to suppose that the coy females sit listening with attentive and critical ear, like judges in a singing competition. As we have already seen, the probability is that a certain *tout-ensemble* of emotional display on the part of the male, in which the song is one item, pulls the trigger of an analogous emotional excitement in the female. There

[1] Newton's *Dictionary of Birds*.

is a tendency to transfer our analytic scientific way of looking at things to birds and beasts that probably leads us into many mistakes. It is extremely improbable that any female bird accepts a suitor on account of his musical or quasi-musical talents.

Another view, which has the great name of Wallace behind it, interprets the love-call as a means of recognition between related forms, and as a signal which brings sparsely scattered birds together. It is highly probable that singing sometimes has these secondary advantages, but the frequent elaborateness of the song seems to require some other interpretation.

Wallace also suggested that singing was a pleasure, and probably helped as a safety-valve for superfluous nervous energy, just as a dance does. Herbert Spencer elaborated the same view that the song is not in any sense a kind of courtship, but simply expressed an overflow of nervous energy. The dog wags its tail when pleasurably excited, the bird works the muscles of its syrinx. This theory is too simple to be the whole truth, but it lays emphasis on a very important fact—the close association between emotion and muscular movements.

There seems much to be said for the thesis well worked out by Professor Groos in his *Play of Animals*—that instinctive coyness has been evolved as a feminine characteristic of great importance as " the most efficient means of preventing the too early and too frequent yielding to sexual impulse. A high degree of excitement is necessary for both, but the female has an instinctive impulse to prevent the male's approach, which can only be overcome by persistent pursuit and the exercise of all his arts." Song is one of these arts by which the male stimulates his desired mate to passion.

Nor is the female's response of less importance in

intensifying the male's excitement, especially in cases where what looks like coquetry is exhibited. Thus, as Groos says, "the female cuckoo answers the call of her mate with an alluring laugh that excites him to the utmost, but it is long before she gives herself up to him. A mad chase through tree-tops ensues, during which she constantly incites him with that mocking call, till the poor fellow is fairly driven crazy. The female kingfisher often torments her devoted lover for half a day, coming and calling him, and then taking to flight. But she never lets him out of her sight the while, looking back as she flies and measuring her speed, and wheeling back when he suddenly gives up the pursuit."

The general conclusions of Professor Häcker's admirable study of the song of birds may be briefly stated.

(1) Love-calls and song probably had their roots in the simple recognition-call or characteristic signal of the species. Gulls and guillemots, hawks and crows do not get beyond this grade.

(2) The calls of the two sexes diverged and a certain amount of specialisation appeared. Thus there came to be special pairing-calls, serving not only for recognition, but also for expressing and suggesting amatory excitement. Cuckoos and woodpeckers illustrate this grade.

(3) As sex dimorphism became more accentuated—the females becoming more passive and coy, the males more active and insistent—the song acquired more and more of its secondary significance as a suggestive excitant, and (unconscious) Sexual Selection came to the aid of Natural Selection. Thrush and nightingale are familiar instances.

(4) Sometimes, however, the singing activity outlasts the breeding or nuptial period. When it overflows into other seasons it partakes of the nature of play, it acquires

a third significance as an expression of a feeling of well-being—a safety-valve for the *joie de vivre.* The yellow-hammer, the water-ousel, and the robin may be mentioned as examples of birds that sing outside of the nuptial season.

THE NATURAL HISTORY OF NESTS

NEST-MAKING is such a characteristic activity of birds that we always think of "bird" and "nest" together. But birds are by no means the only creatures that build nests. The squirrel makes a big nest of moss, leaves, and grass at a fork between two branches of a tree or in a hollow of the stem. The sticklebacks glue together the filaments of seaweed and make a serviceable nest, where the eggs are laid and hatched. Many spiders make true nests of silk, while others bind leaves together with silken threads. The wasp's familiar construction is a house as well as a nest. There are many other nest-makers, yet our almost automatic association of "nest" and "bird" is not without justification, since it is among birds that nest-making reaches its greatest perfection, variety, and beauty.

Uses of Nests

The uses of nests are manifold. They are often adapted to secure the safety of the eggs and young birds by being inconspicuous or by being inaccessible. The period of development and of helplessness lasts about a fortnight in many finches, three weeks in the fowl, over a month in petrels, towards six weeks in the swan, and over seven weeks in the condor, and the risks of discovery are often great. The nest means safety. Secondly, the eggs and the young are cold-blooded—that is to say, they take on the tempera-

ture of the surrounding world, and when they cool below a point, which differs for different species, they cease to develop and soon die. The nest often economises the animal heat of the brooding bird, so that there is little waste. Thus the accomplishment of the development within a suitable time is secured. Mr. Pycraft starts the evolution of nests with birds who gathered a small heap of grass and sticks, and thus kept themselves and the eggs warm and dry when the ground was damp. It is also evident that the nest is convenient for feeding purposes—for the prolonged gastric education on readily digestible food which many young birds require. It is often a convenient temporary prison for the nestlings, so that they are less liable to imperil their lives by making premature excursions. Sometimes the nest serves for a certain amount of home-education. Furthermore, the nest is often a comfortable and secure resting-place for the brooding bird. The breeding period is a climax of activity ; it is soon to be followed by the effort of migration ; the need for rest is obvious.

Dr. Alfred Russel Wallace has elaborated the theory, for which there is much very interesting evidence, that when both the cock- and hen-birds are of strikingly gay and conspicuous colours, as in many kingfishers, the nest is such that eggs and young and sitting birds are concealed from view ; while, whenever the male is gay and conspicuous and the nest is open so as to expose the sitting-bird to view, the female is dull or obscure in her coloration. He shows how this relation might come about in the course of Natural Selection.

We usually associate a nest with concealment or inaccessibility, with some degree of privacy. But there are familiar exceptions. A strong race, like that of the rooks, can afford to indulge their social tendencies even in nesting, and their conspicuous nests challenge attention. We find

a contrast in the cranes, which feed together, play together, and rest together—but nest separately. Sometimes the gregariousness in nesting may be associated with the relative rarity of suitable sites, as may be illustrated by our sand-martins, or by the sociable grosbeaks, which join nest to nest until the tree sometimes breaks down. An eloquent testimony to the advantageous inaccessibility of certain sites is afforded by the huge numbers of birds which sometimes possess them, as is well seen on "bird-bergs" like Ailsa Crag and the Bass Rock, where gannets are so abundant, or, in a different way, in the marshy ground, where thousands of black-headed gulls often nest.

A Series of Nests

Let us work up the series of nests from the simplest to the most complex, following, almost necessarily, the article "Nidification" in Newton's *Dictionary of Birds*. We naturally begin with those birds in which the nest-building—which comes as a serious practical task after the nuptial song or the nuptial dance—is "scamped" or shirked.

The tern makes no more than a mere scraping on the gravelly sand. It is the same with divers, thick-knees, and sand-grouse. The stone-curlew and the night-jar make no nest, nor any preparation of the soil, yet year after year they select the same spot. In the case of guillemots and razorbills, the egg is laid on a bare ledge of rock, and the top-like shape is to some extent a safeguard against being blown over or knocked over.

Many of the gulls, sandpipers, and plovers simply lay their eggs in shallow hollows in the ground, adding a breast-work of stems and leaves as incubation proceeds. The ducks are mostly about the same level of nest-making, but their depression is lined with down. The ringed plover

lays its eggs on the shingle, where they are so like rounded pebbles that they are most effectively lost to ordinary vision; and Professor Newton points out the interesting fact that even when the bird lays its eggs on grassy uplands, it still "paves the nest hollow with small stones."

One of the most charming of ground nests is that of the eider-duck, where a thick quilt of down is accumulated that can be drawn over the eggs when the mother-bird goes down to the sea for food.

In not a few birds the only care is to bury the eggs—a way of securing their safety that recalls suggestively the habits of some reptiles, such as crocodiles, which are historically antecedent to birds. The New Zealand kiwi puts its single big egg in a hollow among the rhizomes of the tree-fern; the female ostrich lays her eggs in a hole which the cock scrapes in the sand, and both birds share in brooding. Some Mound-birds or Megapods bury their eggs in the sand and leave them, while others heap a huge hot-bed of dead leaves over the spot. Dr. Alfred Russel Wallace has told us that many mother Megapods in Celebes come from a distance of 10 to 15 miles to the vicinity of certain warm springs, where they like to lay their eggs. A huge mound is built, 5 to 6 yards high, 30 feet round, and many mothers co-operate. After they have laid their eggs on the mound they depart, leaving the eggs to hatch all untended. If they stayed they would find difficulty in getting enough to eat, for they feed upon fallen fruit; and there is no need for them to stay, since the young birds have a quite unique adaptation—the quill feathers are so long to start with that the chicks can fly away from the mound on the very day of their birth.

Grebes and some rails collect pieces of water-plants and "form of them a rude half-floating mass, which is piled on some growing water-weed"; and while they do not shirk

incubation, they seem to trust partly to the heat of decomposition. Here we have another illustration of the subtle ways in which Bacteria are wrapped up in the bundle of life. They bring about the decomposition which produces heat, and this fosters the development of the unhatched birds. The minions of decay and death are here utilised in the production of life. There are many similar illustrations of a sort of "inter-regnal co-operation," the best, perhaps, being the internal partnership or symbiosis of unicellular Algæ with Radiolarians, with Sea-Anemones and Corals, with simple "worms," and so on. Analogous, though not "inter-regnal," is the intimate and most profitable partnership between Bacteria-like microbes and Leguminous plants, like Clover. This has led us far from the grebe's nest, but the digression may be pardoned, since there is no more fundamental conception in Natural History than that of the Web of Life or the interlinkage of interests in the economy of Nature.

We gradually work up from ground-nests to the earth-mounds on which the flamingos sit, and on to rough platforms like that of the wood-pigeon, through the floor of which the eggs may be seen from below. Making a fresh start, we reach the more elaborate stick nests of the rooks and crows; from these we pass to the heron's, where a little bedding is added; or to the magpie's, where the erection is fenced round with thorns.

An offshoot in a different direction is represented by birds that make burrows or tunnels or excavations of some sort, getting as far as possible into private life. In its safe retreat the sand-martin makes a scant bed of roots and feathers collected from far and near. The kingfisher makes a stranger one of undigested fish-bones. Sheldrakes and puffins often utilise rabbit-holes. The woodpeckers carve out holes in decaying trees; the nuthatch plasters up part

of the doorway. The last instance suggests the case of the hornbills, whose remarkable story has been so well told by Mr. Pycraft and others. The female is weakly and moulting at the breeding-time, and the male shuts her into a hole in a tree-stem. The floor may have to be deepened, or it may have to be raised with dry earth from the termitaries. The doorway is built up, too, so that intruders are readily kept out, while the hole is large enough to let the male bird's bill in. It is on him that the labour devolves of finding food for his mate, and afterwards for his family as well. He is often worn thin with his other-regarding exertions, while the female bird becomes fat. Sometimes, the story runs, the male bird dies without having the reward of even seeing his children.

Cases, like that of the hornbill, where there is some building as an accessory to the nest, point the way to definitely built nests, such as those of the swallow and the house-martin. The swallow's is the more primitive of the two—it is made of mud strengthened with pieces of straw; it is like "half a deep dish," open at the top; it is built against a rafter or a chimney; it has a lining of small feathers and soft grass. The house-martin's is also made of mud, strengthened with pieces of straw or hair; it is built against the wall of a house or against a cliff; it is like a bowl in shape, with its open side against the surface selected, and with a small entrance near the top; there is a lining of feathers, which the martin catches in the air, and pieces of straw. It is difficult to understand how the bowl hangs on to a smooth surface—even to a vertical pane of glass; it is interesting to watch the patient carefulness of the builders, adding about half an inch every morning and no more till next day, so that it hardens well, the whole edifice taking about a fortnight.

A masterpiece along the line illustrated by swallow and

martin is the nest of some of the South American oven-birds (*Furnarius*)—for instance, of that species (*F. rufus*) which is called the "hornero" or baker. The nest is about the size of a child's head, and may weigh 8 to 9 lb.; it is built in a conspicuous place—on a tree, or post, or house-roof. It is made of mud and dung strengthened, as in the swallow and martin, with some hair or dry grass, which is also used as an internal lining. The walls are of almost brick-like strength when well baked, and it is sometimes the work of months to build them. The oven-bird's bill is quite small, and it has to work slowly, pellet by pellet; moreover, when dry weather sets in, it is difficult to get material. But the chief peculiarity of the nest is the presence of an inner chamber; there is an anteroom and a bedroom, as Prof. Trail neatly puts it.

On a different line of evolution, though there is no lack of connecting links, are the felt-work nests, cleverly made of interwoven vegetable fibres and hair—in both cases a good non-conducting material. Chaffinch and goldfinch make open felt-work nests, which may be eked out with spiders' webs and often beautifully disguised with moss and lichen. Similar constructions, masterpieces of skill, are domed in the wren and the bottle titmouse, slung like a hammock in the gold-crest, suspended by a string in certain grossbeaks and humming-birds. There seems to be no doubt that the nest is sometimes *balanced* with lumps of earth—an extraordinary device, when one comes to think of it.

Among these built nests there are endless refinements of detail. The entrance may be narrowed; the outside may be masked; the whole may be swung so loosely that no snake could possibly enter; the lining may be made like a bed of down: thus MacGillivray counted 2379 feathers in the nest of the long-tailed tit. In the nest of the common thrush, which is plastered internally with rotten wood

mixed with dung, or in the nest of the mistle-thrush, which has a considerable foundation of mud, we have instances of the numerous connecting types between hard-built and felt-work nests The tailor-birds make a thread of vegetable fibre, and sew together the edges of a couple of leaves ; the fantail warbler also uses a thread—knotted at the end—to bind grass-stems into a canopy over its nest. Of certain warblers (*Aedon* and *Thamnobia*) it is said that they invariably lay a piece of snake's slough in their nests, like the horseshoe by the house-door.

The series of typical nests might be greatly prolonged, but we must bring it to a close with a reference to what is perhaps the most extraordinary of all nests—that of the sea-swift (*Collocalia*). The bird occurs in great numbers in Indian and Australian regions, and usually nests socially in caves, both by the sea and among the mountains. The peculiarity of the nest—the well-known " edible bird's-nest "—is that it normally consists of the dried secretion (largely mucin) of the salivary glands. When the first nest has been gathered, the bird sometimes builds an inferior type of nest, including a considerable quantity of vegetable matter glued together with the hardened salivary juice. It is worth recalling the fact that not a few of our British birds moisten with their saliva the vegetable fibres and the delicate twigs which they use for nest-making, thereby rendering them more pliable. It seems likely that the inferior nests of *Collocalia,* in which vegetable fibre predominates, represent for this genus a primitive rather than a degenerate type.

The Nature of the Nest is Specific

We have seen that there is a long inclined plane from no nest at all to the most elaborate nest, but the important fact

is that the character of the nest is distinctive of the species. Each kind of bird keeps to its own kind of nest—*with relative constancy*. In short, the nature of the nest is specific, with a measure of variability such as we find in structural specific characters. The blackbird is first cousin of the thrush, but every country schoolboy knows that the nests are very different, and so it is all round. When birds build on an unusual site, or when they nest in a locality where their favourite materials are scarce, the nest may vary considerably from type, and we read every year in the newspapers of extraordinary vagaries (doubtless more extraordinary to us than to the bird !) as to site and materials. Apart from cases of nests inside station-lamps or letter-boxes, there is considerable variability in the open country. The Golden Eagle may use a ledge of rock, a forest tree, or even the thick herbage ; the heron may rest on a lofty tree, in a sea-bank, or in the open fen. It is well known that a bird may lazily use another bird's nest, and the habit has become normal in the European cuckoo. The familiar sight of sparrows evicting swallows is suggestive of the possible origin of a regularly parasitic habit—if it could be regularised so as not to kill off the swallows !

The Fashioning of the Nest

It is possible nowadays to see in a cinematograph series the whole business of nest-building—in a few cases of more or less exposed nests. In regard to many more difficult cases, persistent and patient observation—with the help of a good field-glass—has enriched science with detailed descriptions of one of the most interesting of animal activities. It is difficult, however, to venture on any general statements. The hens do most of the work of building the cradle, but the cocks often help. As birds are practically

handless—a sacrifice involved in the turning of arms into wings—the bulk of the work is done with the bill and with the feet, and the body is used to mould the framework, the bird turning round and round inside the growing nest, making it fitter at every turn with a poke of the bill and a thrust of the foot. The busy bird suggests at times an extremely energetic and somewhat fussy sculptor, working on his clay, dabbing here and dabbing there, smoothing down and ruffling up, and pausing every now and then to look at it with critical appreciation. But when we look at the finished product, such as the nest of a chaffinch, we must stand amazed at the artistic achievement. It may be safely said that the wonder grows upon us as we probe deeper into the details of the nest.

Subjective Aspect

It is not difficult to observe how a bird uses its bill and feet in fashioning the nest, but it is very difficult to get near the inward spirit. The only course is to select the interpretation that fits the facts best and makes fewest assumptions. Is the art of nest-building *instinctive* ? That is to say, has the bird an inborn power of fashioning a nest of a particular type without education or experience? Does it require only what the Germans call an *Auslösungsreiz* —a liberating stimulus—to pull the trigger of an innate capacity ? And is this innate capacity the outcome of an age-long selection which favoured those individuals whose brain varied in the direction of useful constructive art ?

In support of this way of looking at the nest, there are a few observations, *e.g.* that canaries that had never seen more than a shop-made felt nest have been known to make an effective nest of moss and hair ; or that a greenfinch, incubated by a canary in a canary's nest, made, in the course

of time, a true greenfinch nest of fibrous roots, moss, wool, and horse-hair.

There is also an indirect argument in support of the view that the fashioning of the nest is instinctive; it is based on the fact that the nature of the nest is usually specific. That each bird keeps, as a rule, to its own type of nest does not exactly prove that the whole business is instinctive; but it points in that direction, and it seems to us to rule out the view that each nest is the expression of independent and unprejudiced artistic skill. It must be noted, however, that so great an authority as Dr. Alfred Russel Wallace refuses altogether to admit this argument. According to his view, "each species uses the materials it can most readily obtain, and builds in situations most congenial to its habits. . . . The materials of birds' nests, like those used by savage man for his house, are, then, those which come first to hand; and it certainly requires no more special instinct to select them in one case than in the other." Similarly, he interprets the characteristic architecture of the nest in terms of the general habits of the species, the nature of the tools (bill and feet) they have to work with, and the material they can most easily obtain.

The non-instinctive theory, supported by Dr. Wallace, lays emphasis on imitation and tradition. While a bird may inherit an indefinite tendency to build a nest at the proper time, the manner of its building depends on the extra-organic tradition of the species. From generation to generation there is a "tradition" registered in the nest itself, which is, in a sense, a "permanent product," and including all the possibilities of imitation and suggestion from previous and contemporary nest-builders. Even with human mothers, where there is intelligent awareness rather than vague instinctive prevision, how important is the social tradition of what is fit and proper in the way of provision for the future

child—a tradition operative in various ways—through memory of what has been seen, through models to imitate, and through permanent registration in books. Similarly, there may be a distantly analogous tradition among wrens and weaver-birds, thrushes and chaffinches, as to the fit and proper nest to build. In support of this view, it is said, for instance, that chaffinches transported to New Zealand no longer build the typical chaffinch nest. They have got beyond the tradition.

Against Wallace's theory is the obvious fact that the young birds do not see the building of the nest in which they are hatched, but he supposes it to be sufficient that the young birds before they leave the nest have " ample opportunities of observing its form, its size, its position, the materials of which it is constructed, and the manner in which those materials are arranged." It may also be that the young birds follow the lead of their seniors in nest-building the following year, learning as they go along, and in some cases they may not be ready for nest-building the first Spring, and thus have further opportunities for watching what the older birds do. But the fact is that careful experiments are necessary before we can decide between the view that nest-building is in the main an instinctive activity and Wallace's conclusion that he cannot find in nest-building " a particle of evidence to show the existence of anything beyond those lower reasoning and imitative powers which animals are universally admitted to possess."

Mr. Pycraft, on the other hand, writes : " In spite of the dogmatic assertions of this eminent naturalist, there is absolutely not only no evidence in support of his contention that birds build by imitation, but all the known facts are directly against him." . . . Thus " wild birds taken from the nest before they can see, and kept in captivity under suitable conditions, will, at the appropriate time, build a

nest typical of their species." It is by an extension of experiments of this sort that the interpretation of the subjective aspect of nest-building will be raised above the level of *opinion.*

It may be possible to combine the two theories in the view that the fashioning of the nest is in greater part instinctive, yet in some measure traditional, while we can hardly doubt there is often a spice of personal intelligence on the artist's part—especially evident when quite novel sites and materials have to be dealt with. After quoting some evidence, Professor Lloyd Morgan concludes, in his *Habit and Instinct,* that " some birds build their nests true to type, without opportunities or with but the slenderest opportunities of imitation or instruction. It appears to me that the evidence before us justifies the conclusion that nest-building in definite ways is an instinctive activity ; but that it is modifiable by individual experience."

BIRDS' EGGS

ALTHOUGH the eggs of birds are by no means very typical eggs, they are always those which the word first suggests, and they perhaps deserve the first place in our consideration, for they are interesting above all other eggs, as the enthusiasm of the "oologists" amply testifies. "In enthusiastic zeal for the prosecution of their favouritive researches," Prof. Alfred Newton writes, "they have never yielded to, if they have not surpassed, any other class of naturalists. If a storm-swept island, only to be reached at the risk of life, held out the hope of some oological novelty, there was the egg-collector. Did another treasure demand his traversing a burning desert or sojourning for several winters within the wildest wastes of the Arctic Circle, he endured the necessary hardships to accomplish his end, and the possession to him of an empty shell of carbonate of lime, stained or not (as the case might be) by a secretion of the villous membrane of the parent's uterus, was to him sufficient reward." Eggs can be studied scientifically like other things, and Professor Newton goes the length of saying that hardly any branch of the practical study of Natural History brings the inquirer so closely into contact with many of its secrets. It is true that collecting birds' eggs may be no better, and is often much worse, than collecting postage stamps; but if one ponders over the eggs and their problems, there is abundant opportunity for scientific work, and there have been some notable results. Thus we must credit

the students of birds' eggs with being the first to appreciate the intimate relationship between gulls and plovers—which was afterwards proved up to the hilt on anatomical lines by Huxley and others.

What is roughly called the yolk of a bird's egg is the true egg-cell, which has been enormously dilated by its store of reserve material. A drop of genuine living-matter lies like an inverted watch-glass on the top of the yolk, and from this drop the whole of the embryo is formed, the yolk being simply a nutritive legacy. All round the yolk there is a delicate vitelline envelope, and outside this lies the white of egg or albumin, secreted by the walls of the oviduct, and also nutritive. Round about the white of egg there is a delicate, tissue-paper-like double shell-membrane, the two layers of which are separated at the broad end of the shell to form an air-chamber. Outside the shell-membrane is the porous shell, which is formed from the walls of the oviduct. It is often stained with pigments, and it consists mostly of carbonate of lime, with a small proportion of carbonate of magnesia and phosphate of lime and magnesia. Experiments have shown that a hen can make a normal carbonate of lime shell, although there is no carbonate, but only other salts of lime in its food.

One of the first facts that strikes us in connection with birds' eggs is that there are so few in a clutch, compared with the number in lower animals. The wren may have eight or nine eggs, the mallard a dozen, and the long-tailed tit as many as twenty; but these large numbers are quite exceptional. Many birds, such as the golden eagle and the black guillemot, usually lay only two; while others, like the common guillemot and the little auk, have come down to one. There are two ways of looking at the smallness of the family. On the one hand, birds are typically flying

creatures, and this limits the number of relatively large eggs that they can bear at a time. On the other hand, the great care that birds take of their eggs and young makes survival, in spite of the small family, more practicable. And, again, it must be remembered that many birds are taxed to the utmost in feeding their young brood, so that in this way an indirect check would be put on large clutches.

The size of the egg depends, as in most cases, on the amount of nutritive material or yolk, not on the amount of living matter that there is to start with. In general it bears some relation to the size of the bird. Of European birds, the swans have the largest eggs, and the golden-crested wren the smallest. It is said that the egg of the extinct Moa of New Zealand sometimes measured 9 in. in breadth and 12 in. in length, while that of the extinct Æpyornis of Madagascar held over two gallons—some six times as much as an ostrich's egg, or a hundred and fifty times as much as a fowl's.

It cannot be said, however, that the size of the egg is more than generally proportional to that of the parent; for, while the cuckoo is much larger than a lark, the eggs of the two birds are about the same size; and, while the guillemot and the raven are about the same size, the eggs the former are in volume about ten times larger than of those of the latter. Hewitson pointed out that "the eggs of all those birds which quit the nest soon after they are hatched, and which are consequently more fully developed at their birth, are very large." Professor Alfred Newton adds that "the number of eggs to be covered at one time seems also to have some relation to their size." He contrasts the snipe and the partridge: the former has four eggs, the latter as many as twelve; the eggs are equal in size, and the chicks in both cases are able to run about as

soon as they are released from the shell. The snipe, though a much smaller bird, can afford to have eggs as large as those of a partridge, because it has only four, which always lie with their points almost meeting in the centre. We believe, however, that some account must be taken of the habits of the various birds, and that a highly nutritive sluggish bird, not flying about much at the breeding season, will naturally have relatively larger eggs than a bird of sparser diet and more active habit.

Birds' eggs show considerable diversity in shape; for, while the majority are oval, many are "pear-shaped," as in guillemot and snipe, many are approximately spherical, as in owls and kingfishers, those of the sand-grouse are obtuse at both ends, and those of grebes biconical. Even within the species or clutch there may be considerable variability, and a collection of abnormal hens' eggs presents a whimsical appearance. There is, however, a norm for each type, both of shape and size, and it is interesting to observe that after abnormalities "regulative changes" bring subsequently laid eggs back to the normal—a phenomenon that leads us to the very heart of vitality.

The problem of the immediate factors that determine the shapes of the eggs of birds has been discussed in a very interesting paper by Professor D'Arcy W. Thompson (*Nature*, 4th June 1908, pp. 111–113). The egg, consisting of a slightly extensible membrane filled with an incompressible fluid, is subject to external pressure from the radially contractile oviduct, and an equation for the shell that is formed can be worked out. It is pointed out that, from the nature and direction of the usual peristaltic wave in the oviduct, the pressure will be greatest somewhere behind the middle of the egg; in other words, the tube is converted for the time being into a more conical form, and the simple result follows that the anterior end

of the egg becomes the broader and the posterior the narrower.

But, while the primary reason why an egg has a particular shape is doubtless to be found in the conditions of pressure within the muscular oviduct, that is not inconsistent with finding that the shape is sometimes adaptive to particular conditions in the life of the bird. Two instances of this adaptiveness are well known. Eggs which are markedly pear-shaped "are mostly those of birds which invariably lay four in a nest; and therein they lie with their points almost meeting in the centre, and thus occupying as little space as possible and more easily covered by the brooding parent." But the guillemots and razor-bills have also very markedly pear-shaped eggs, and the bird usually lays only one or two. Darwin pointed out, however, that this shape of egg was particularly well adapted to the risks of the narrow rocky ledges on exposed cliffs, where the eggs are laid without even an apology for a nest. If the egg be jostled by a bird's foot or whirled by the wind, it tends not to roll along, but to rotate on its short axis without leaving the spot.

Eggs differ not a little in the *texture* of the shell. In different families there is, often at least, a characteristic shell-structure. Thus a cuckoo's egg can be recognised in a clutch when it has the same colour as the eggs of the foster-parent. There are said to be differences between the egg-shells of the carrion crow (*Corvus corone*) and those of the hooded crow (*Corvus cornix*), which are two very closely allied species, or, as some would say, colour-varieties of one species. In some cases, it is said, the shell registers hybridism—a very remarkable fact. It is another illustration of the great, though still vague, truth that the living creature is a unity through and through, specific even in the structure of the egg-shell within which it developed. For,

although the shell is secreted by the walls of the oviduct, it seems to be in some measure controlled by the life of the giant-cell—the ovum—within.

It must be clearly understood that, if we compare a hen's egg with frog's spawn, what we call "the yolk" is equivalent to the dark-coloured egg-cell which lies within the sphere of jelly; the latter is equivalent to the white of egg; but the frog's egg has no hint of a shell!

The surface of the shell may be glossy or of very fine grain, as in the kingfisher; or opalescent, as in some woodpeckers; or burnished, as if glazed, as in the tinamou; or pitted, as in the emeu; or greasy, as in ducks; or rough, with a chalky film, as in the gannet. In a few cases the chalky layer hides a deeper layer with fine colouring.

But the most striking feature of birds' eggs is their diversity of coloration, which is often strikingly rich and beautiful. Thanks to the spectroscopic work of the late Dr. H. C. Sorby, who touched many departments of Natural Science with a masterly hand, we know of seven well-marked pigments in egg-shells. Six of these are allied chemically to hæmoglobin, the pigment of the blood; the seventh (lichenoxanthin) is common in plants, especially in lichens, and may possibly be due in some curious way to minute fungi in or on the egg-shell. The other pigments are exuded into the oviduct as the eggs pass down, and there is some reason for connecting their production with the bursting of the eggs from the ovary.

In any case, minute drops of pigment are exuded from the lining of the oviduct; they adhere to and stain the egg-shell, which is still soft. If the egg be at rest for the moment, the pigment-drops are fixed as circular spots of colour. But as the egg is usually rotating onwards down the oviduct, the spots of pigment tend to become smeared

splashes, or long streaks, or irregular blotches—often conspicuous against a ground colour of white or of some previously deposited pigment. This is only the A B C of a difficult matter; but with this simple fact clearly focussed in the mind, it is very instructive to look over a collection of eggs and interpret the precise well-fixed marks, the clear-cut edges, the hair-lines, the spirals, the long-drawn-out splashes, as indicative of the rest or the movement of the egg during the period of painting. In many cases it has obviously moved much before the paint was dry. In this connection we must remember the general uniformity of natural process. Given the same kind of bird, the same size of egg, the same calibre of oviduct, the same pigments, the same rate of egg-movement, and the coloration of the egg will *tend to be* the same. And it is interesting to know experimentally that abnormal conditions, such as fright or captivity, may disturb the natural painting of the egg-shell, or suppress it altogether. Thus we have seen, for instance, a woodcock's clutch with pure white eggs—most unprofitably conspicuous in the wood.

The next point of importance is that the coloration of birds' eggs is variable, and sometimes very markedly so. Notoriously variable are the eggs of the Black-Headed Gull (*Larus ridibundus*)—from unspotted pale blue at one extreme to very dark brown, with darker spots, at the other. The eggs of the rook, the guillemot, and the cuckoo are also good illustrations of variability. The bird cannot alter the colour of the egg by willing it; she is not influenced by surrounding colours; the eggs are only to a slight extent modifiable by external influences. There is no doubt that the variability in colouring is due to a peculiarity in the constitution of the mother-bird. The important fact has been noticed that, when a mother-bird has begun to lay eggs of a peculiar coloration, she may continue to do so for

years. The pleasant brown colour of the eggs of some fowls is due to a variation which breeds true and does not blend; by taking certain well-known precautions in breeding it can be, as it were, grafted on to a stock laying white eggs.

We have described in a simple way the mechanism by which birds' eggs are coloured; we have seen that most of the pigments are allied to the red pigment of the blood; we have noticed that in many cases birds have not yet quite settled down to a stereotyped kind of egg-coloration; we must now ask whether the colouring has any selective value, or, in other words, any vital significance.

In some cases, where the eggs are well hidden or are almost quite safe, it is difficult to find any significance in the colouring. It may express the unity of the organism, but it seems to be useless in the present condition of the species. Similarly, the colouring of deep-sea animals, or the colouring of withered leaves, cannot be shown to have any direct utility. Similarly, some of the internal organs of animals have very fine colours, absolutely determined, never haphazard, but yet valueless as regards optical effect, because invisible.

On the other hand, it seems quite impossible to doubt the occasionally great vital value of the coloration which in other cases may be a negligible feature. We refer, of course, to those cases where exposed eggs are inconspicuous because their coloration harmonises so well with the surroundings. This is particularly striking in many members of the Plover and Gull tribes, where it is almost impossible to exaggerate the difficulty of finding the eggs in their appropriate surroundings. This is a particularly instructive case to think over, for one can understand that, given an abundant crop of colour-variations and a severe elimination-process, survival would be with the appropri-

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ately coloured eggs, or, in other words, with those birds whose constitution turned out the appropriately coloured eggs. This is not inconsistent with the view for which there is something to be said that birds may to some extent choose out spots which suit the colouring of their eggs.

WITHIN THE EGG

A BIRD'S life begins when there comes about an intimate and orderly union of the maternal and the paternal inheritances—the result of which is a new creature, not free to be or do anything it likes (a sort of freedom which has never existed, and would not be worth much if it did), and yet not fated to be a mere echo of its father or its mother, but with some measure of originality, or individuality. It is a new creature, in some ways quite unpredictable, though we may be able to indicate beforehand some of the alternatives of expectation. In this variability we have, in part, the biological basis for the doctrine of personal freedom, which tends to be dimmed by insistence on the inexorable continuity which the hereditary relation also implies. The individualised young creature, with a freedom of contingency, at least, acts on and reacts to its nurture, until there is formed a sort of personality, or character. This is a product of the external as well as of the organic heritage—and it may lead on to a truer freedom than that of mere contingency. Even in the bird there is a self—it may be a very unique self —with the power of being and doing differently from its immediate ancestry. In so far as it avails itself of its relative newness to respond or to fail to respond to environmental nurture, there develops an individuality, opposable to the trend of the natural inheritance, even capable of approximating to the ethical idea of freedom.

The development of a bird is apparently a very smooth and orderly process. There are no crises, no sharp turns, as

in the life-history of a frog or a butterfly. There is, indeed, a very interesting "critical point," as it is called, when for the first time the specific characteristics emerge. They have always been there, of course, but have not hitherto found more than generalised expression, as far as we can see. But there is no crisis at that "critical point," so far as we know. The process is smooth and orderly; it is like the unfolding of a bud, except that there are no visible preformed parts; it is like the working out of an idea in a master-mind who has no hesitation or loose-ends or fluffiness in his concepts.

It may take a long time, comparatively speaking—six weeks in the condor, three in the fowl, two in the finch—a long time compared with the extreme rapidity with which the complex architecture of many an insect is built up. And yet what a short time, when we remember the thousands and thousands of cell-divisions that have to occur, each as complex a business as the crowning of a king! What a short time, when we remember that the developing embryo begins as a single cell, with a nucleus half paternal, half maternal, and that it becomes within the shell a bird, which may be able to run about whenever the shell is broken, which is in one family (Mound-birds) able to fly when it is born. What a short time, when we remember that the developing bird has to recapitulate in some measure the racial history of Vertebrates, to climb up its own genealogical tree.

The stages of development are, in the case of a few birds, such as hen, duck, and even kiwi, so well known from day to day, that exact figures and models are obtainable. There is no doubt whatever that some of the stages are only intelligible when we look backwards as well as forwards. They have a retrospective as well as a prospective significance; they hint at past history. Thus there are functionless gill-clefts which point back to an extremely remote aquatic ancestry.

The luminous idea that development resumes evolution,

that ontogeny recapitulates phylogeny, that the developing creature climbs up its own genealogical tree, has been of service, but it has also been mischievous. It is so easily exaggerated. Till the sixth day in the case of the chick the embryo is not visibly a bird embryo; it might be a reptile embryo as far as external inspection tells us; but it is never like a fish, nor ever like any reptile, it is only like an embryo-fish, an embryo-reptile. The recapitulation is rather in the development of organs than in the development of the embryo as a whole. The appearance and disappearance of the notochord, the gill-clefts, and the visceral arches, the stages in the development of heart and circulation, the brain and the skull, are wonderfully like recapitulations, and we do not know how any one could interpret the appearance and rapid disappearance of old-fashioned organs like the notochord and the gill-clefts except as vestigial relics of long-past racial history. But it must be emphasised that the so-called recapitulation is a very general one: that it is seen rather in the stages of organs than in the phases of the whole creature; that it is a recapitulation of embryonic stages, not of adult forms; that it is often condensed and, as it were, telescoped; and that in very early days there are evidences of the specific bird that is to be.

Embryology is entirely a modern science. Though Aristotle (384–322 B.C.) watched the heart-beats of the still unrecognisable chick within the egg, and had hold of the idea that development is a progressive differentiation, he had practically no successors before Harvey (1578–1657).

Harvey got a grip of the fact that almost every living creature is produced from an egg—*ovum esse primordium commune omnibus animalibus*—and of the fact that the initial stage is not a preformed model, but something apparently simple, in which, as he said, "no part of the future organism exists de facto, but all parts inhere in

potentia." But Harvey had no way of accounting for the wonderful primordium with which he started, *at times* he was not even sure that it was entirely due to the parents. " Neither the schools of physicians nor Aristotle's discerning brain have disclosed the manner how the cock and its seed doth mint and coine the chicken out of the egg."

We now know this much clearly, that the primordium owes its peculiar virtue to the fact that it is continuous through unspecialised cell-lineage with the fertilised egg from which the parent arose. There is a sense, as Galton said, in which the child is as old as the parent, for when the parent's body is developing with manifold differentiation from the fertilised ovum, a residue of unaltered, unspecialised germinal material is kept apart to form the reproductive cells, one of which may become the starting-point of a child. Similarly Weismann, generalising from cases where the lineage is visibly demonstrable, maintains that the germinal material (germ-plasm) which starts an offspring owes its virtue to being materially continuous with the germinal material from which the parent or parents arose. Since Virchow's *Cellular-Pathologie* in 1858, there has been a growing acceptance of this idea of germinal continuity, which makes development a little less of a puzzle. There is a beadlike continuous lineage of germ-cells, of which individuals are the mortal pendants ; the parent is as much a trustee of the germ-plasm as the producer of the child. In a new sense, the child is a chip of the old block.

We do not know how the potentiality of a bird is condensed into a little clear drop of protoplasm with a nucleus lying on the top of the yolk, just as we do not know how the potentiality of doing very effective and wonderful things is condensed into the pin-head brain of the exceedingly unteachable ant ; but we do know now how the germ-cell differs from the cells of the body of the parent, being, through

unspecialised cell-lineage, a direct descendant of the fertilised egg from which the parent arose. The idea of germinal continuity has brought much light into biology.

We know in the case of the chick, for instance, exactly how stage succeeds stage, often in a circuitous fashion as if not going straight to the end; but we do not know the mechanics of development, how each stage conditions the next, except in a vague sort of way. The *Archiv für Entwicklungsmechanik* contains, however, many papers which show that some analysis is quite feasible. In some cases we know quite precisely that e will follow a, b, c, d, but we do not know how it comes about. The descriptive account is sometimes nearly perfect; the causal analysis lags far behind, especially because (1) development is growth, and growth is of the very essence of life; and (2) development is the expression of a mosaic inheritance which is gradually realised. Is it not very difficult often, in spite of our theories of association, selective memory, controlled attention, inference, and so on, to give any feasible account of how one thought grows into a bigger and better one, though we feel sure that the idea had a development, is a product of conscious or subconscious antecedent stages? The same sort of puzzle faces us in the study of development. Out of the apparently simple there emerges the obviously complex; we see the stages, but we do not yet fathom the *how* of them. We often think of a rich inheritor with a thick cheque-book; we can give some consecutive account of him, but ever and anon he surprises us by a new departure, which means that he has cashed part of his legacy. So the developing bird is progressively cashing, *i.e.* expressing or realising, part of its inheritance. But its ways are very orderly.

In a few hours the apparently simple drop of formative protoplasm has become a disc of cells, in a few days it has passed through the great events in vertebrate development—

the making of the brain and spinal cord, the making of the transitory skeletal axis (the notochord) and the foundation-laying of the future backbone, the formation of the food-canal, the establishment of the musculature, the body-cavity, and so on.

Within a few days, it may be a week or more, the embryo is recognisably a bird-embryo, within a few more days it is recognisably a particular kind of bird—with cuckoo's feet or kiwi's breast-bone, or the hoatzin's claws, or a pattern of feather-tracts (before there are any feathers), which is distinctive in most birds. Soon, moreover, it is visibly, as it has been throughout invisibly, a particular species of bird. Even audibly, for one may hear from within the shell the characteristic call-note of the future bird, *e.g.* of peewit, or gull, or coot, speaking before it is born.

Not infrequently, however, some of the individual characteristics of the bird are, as it were, held back from expression—the hereditary cheque not cashed—until some time after birth. The facts go to show that this retardation of expression is especially marked in regard to characters which have been fixed relatively late in the racial history of the species.

To put it concretely, it is a noteworthy fact that the characteristic bills of spoon-bill, humming-bird, and scissor-bill are not expressed until long after birth, just as part of our own inheritance is often held latent for many years until the appropriate, or it may be, to us, inappropriate time for its expression comes—when its liberating stimulus—*Auslösungsreiz*—arrives.

Meanwhile the patient task of incubation proceeds. Usually the hen sits ; sometimes the two parents co-operate ; rarely the patience is wholly masculine, as in the bustard-quails. Sometimes, moreover, the incubation is left to the

sun, or to the warmth of decomposing vegetable matter, as in many mound-birds. And the cuckoo is notorious for having found out the device of being maternally virtuous by proxy.

An important point, of course, is that the embryo is very imperfectly warm-blooded, and that the development will slow or even stop if there be not a requisite warmth, and that even the fledglings are very imperfectly warm-blooded and may die if left for some hours exposed. Young birds are very imperfectly warm-blooded in those cases where brooding is habitual, and it is interesting to notice that old-fashioned primitive birds, such as the Emeu (like old-fashioned primitive egg-laying mammals), are also, as adults, imperfectly warm-blooded.

Of great interest is the epoch—after two to six weeks—when the embryo, well-formed, and it may be with a suit of feathers, has used up its legacy of yolk, and must emerge. It thrusts its bill at the broad end of the egg into the air-chamber, which has been gradually growing larger; it gets its lungs inflated for the first time; it becomes suddenly more vigorous and writhes in its birth-robes; it pecks with its egg-tooth at the shell, makes a crack, a hole, a rent—and sinks squirming, like a half-made thing, on the floor of the nest, or steps boldly out into the world of action and freedom.

LEARNING TO LIVE

IN illustration of the concrete study of young animals, we propose in this chapter to give a short account of some observations made a number of years ago on the behaviour of young gulls (*Larus ridibundus*) artificially hatched. Our study was too slight to afford important results like those reached by Professor Lloyd Morgan and others, but it had its interest, especially as the observations relate to a thoroughly wild bird, and not to the domesticated chick.

The gullery which furnished the material for this study was for many years one of the sights of Spring. The removal of the bird—the black-headed gull—from the list of those protected has reduced the colony to very small dimensions, which is regrettable from a natural history point of view, and also economically, since the bird is in the main insectivorous, and does much good in destroying wireworms and similar pests. But that by the way; the gullery was a sight to see—with four or five thousand birds nesting in a somewhat circumscribed swampy area. When they rose in alarm and filled the air with their wings and deafened us with their harsh cries, we got a vivid impression of the abundance of life. This was increased when the eye became accustomed to detect the hundreds of nests. Another general fact of which one was apt to receive unpleasant proof was the security of their nesting haunt from human intrusion, for the foothold was treacherous in the extreme.

Repeated visits made one familiar with the gullery,

and a few observations may be noted. Although the thousands of birds were extraordinarily quick to take alarm, or at least to rise excitedly into the air, they submitted in two or three minutes to the presence of an intruder if he sat quite still under a covering of sacking. The birds would then come within arm's length and settle down, though the shape of the observer, who was peering through holes cut in the sacking, formed the most conspicuous object in the immediate environment. By this method of observation it was possible to make sure of the fact that the same bird came back to the same nest. That is, of course, what one would expect them to do, but as there may be hundreds of nests within a small radius—at least half a dozen on an area equal to that of an ordinary dinner-table—and as the very uniform stretch of mud, tussocks, and bog-bean stems presents to ordinary eyes few distinctive marks, and as there is continuous rising, squabbling, and re-settling, it seemed well to take some pains to fix the attention on birds with some slight peculiarity in their plumage, and to prove that they came back to their proper nest. The extraordinary variability of the eggs may facilitate the recognition of the nest during the day. On one occasion it was observed that a very young nestling of the first or second day, which had tumbled out of its own nest and crawled to the next one, was accepted without demur, which seems to be frequently the case with birds that nest in large companies. On the other hand, older youngsters, able to run about, were pecked at very viciously when they came near a brooding bird.

It was worth while year after year to look at hundreds of nests to get an indelible impression of the extraordinary colour variability. No words can describe it, several plates are necessary, but as the eye passed from, for instance, unspotted pale blue to very dark brown with

darker spots, one felt that the bird had not settled down to any particular colour or pattern. As in another well-known case, the guillemot, the coloration is still varying copiously. In both cases, it may be said that the locality in which the eggs are laid makes the colour immaterial, or at all events unimportant. One felt also that if circumstances should arise in which it became of survival value that the eggs should be of a particular coloration, there was present abundant raw material from which to select.

Some eggs removed from the nests were transferred to an incubator in the laboratory, and hatched there—the usual method in an inquiry into instinctive behaviour. Observations immediately after the artificial hatching were rendered difficult by the imperfect warm-bloodedness of the young birds. When removed from the incubator or from a warmed box they were in a few minutes oppressed by the cold, and uttered their cry of discomfort almost continuously. As observations under conditions of discomfort are fallacious, the birds were at first studied only for a few minutes at a time.

Hatched with open eyes, which did not wink on the approach of a finger, the young birds showed no sign of any fear. A notable fact indeed was their extraordinary self-possession throughout, though suspiciousness gradually grew on them. It may here be noted that in early days the presence of a cat or a dog did not seem to excite any attention ; later on there was complete attention, but no apparent fear. A gull two or three weeks old will run at a fox-terrier and peck its nose ; but later on, before they fly off, when about a month old, the birds utter the alarm cry and retreat on the sudden appearance of a cat or dog.

Within a few hours after hatching the young birds pecked at a finger or at a spoon, held close to them, with or

NESTING-PLACE OF KITTIWAKES

(VII)

without food, but there was a lack of precision in their aim. Many of the first day's pecks were misses, but the learning was very rapid, and it was noted that the young gulls were far ahead of young coots in the precision of their early pecking. Even on the first day some fed repeatedly and heartily, but this varied with the individual.

Some preening was observed on the first day, and the general vertebrate action of raising the hind foot to scratch the head—seen in frog, lizard, chick, kitten, etc.—was frequently noticed. Almost from the first, too, there was a slight use of the wings in balancing.

On the first day a young bird turned its head towards the cheep of another in a separate compartment of the incubator and cheeped *as if* in response. A third, still within the egg (chipped), often uttered a note, twice repeated, when the others cheeped. But only a few observations of this sort were made. Little or no attention was paid to noises, except to a prolonged low whistle, which was followed by cowering, even on the first day after hatching.

On the second day the pecking was vigorous and precise; the young birds followed bright objects by moving the head and neck, and pecked at them in motion. They attended to sleeve-links, ring, silver spoon, and similar shining things. They would look up in answer to a tap on the window of their cradle—perhaps because of the actual vibration, but they took no heed of snapping fingers, of the ring of a spoon on a glass beaker, of the rubbing of a cork on glass, and many other striking noises. They shrank a little from a sharp hand-clap close to them, but did not cower, and it may have been the gust of air that affected them. A prolonged low whistle again made them crouch in silence, but after a number of trials on one day (the second) one of them entirely ceased to respond. It

would be interesting to discover whether there is in the normal environment of the gullery some alarming sound corresponding to the low whistle, for that and a hiss were the only sounds (apart from their neighbours' cheeping) that seemed to fix their attention and induce cowering. Later on the birds learned to associate certain sounds with their food supply.

The sensitiveness to cold, which unfortunately led to a repeated reduction in the number of young birds, was still very marked on the second day. Even on a rug in front of the fire they would creep into the observer's hands or crawl up his sleeve, apparently for warmth. At the pond many of the young birds seemed to be in a state comparable to cold coma, and it may be suggested that some measure of this may be useful in tending to prevent premature excursions which would in many cases inevitably land the birds in the water.

As is well known, the adults are very combative birds, and it was interesting to observe a fight early on the second day of life. The child is father of the man. Beth pecked at Aleph's bill, and Aleph responded, beginning a tussle so forcible that separation seemed advisable. It was striking in connection with these youthful tussles to notice the interlocking of the bills, just as may be observed in the combats of the adults. As has been pointed out by Bordage, these bill-wrestlings are of biological interest in connection with the regenerative capacity shown by injured beaks in various kinds of birds, such as storks. At this high level in the animal series it is rare to find much regenerative capacity, and its retention in the case of birds' beaks may be in part interpreted in the light of the fact that injuries to the beaks are frequent in natural conditions. For Lessona's famous law of the distribution of regenerative capacity is that it tends to occur in those animals and in

those parts of animals which are in the natural condition of their life very liable to non-fatal injury.

It is difficult to suppose that the second-day combat was other than an early expression of the combative instinct ; it could hardly be due to hunger in the case of Aleph and Beth at any rate, for between their first and second days they were fed at 3.30 a.m., at 6 a.m., at 9.30 a.m., and so on till 6 p.m. They would only take a little at a time, but that greedily enough. It is probable that in natural conditions the mother gives them mouthfuls with great rapidity, but it seems very difficult to observe the act of feeding at the gullery.

On the third day one of the young gulls had a bath, and showed the completeness of the cleaning instinct. The head was ducked sideways, shaken about, and re-ducked precisely in the adult fashion, and this on a first experience of water in bulk, and of course without any example. After some cleaning the bird drank in the usual chick fashion. Another bird, Omega, was put on its third day into a deep bath : it screamed for a few seconds, then settled down to paddling in a thoroughly efficient fashion, but with a tendency to swim backwards. It washed its head thoroughly, cleaned its bill with its foot, turning round and round in the water like a top, and after the bath it preened itself. Repeated experiments with different birds showed perfectness of swimming powers without experience or imitative stimulus, and perfect preening after the bath.

In several cases the bath seemed to be premature, for it was followed by extreme weakness and inability to stand upright. After various treatments—warm milk, a little oil, massage, and drying in a warm place, there was rapid restoration to normal vigour.

Omega on its third day was fighting with X of two

days ; a vigorous hiss on the observer's part made it cower down into a corner, as if thoroughly frightened. The fact is worth recording, since the almost complete absence of fear was characteristic. The same bird Omega fought on its third day with Y of two days, and they showed their bills gripped in the adult fashion.

The observations made, though far from thorough, left a strong impression that the wild bird is in some respects more endowed at birth than the chick—than even the cleverest chick, for they differ considerably.

For instance, while Lloyd Morgan's chicks would gorge themselves with useless or hurtful things, such as red-worsted worms, the young gulls were from the first judicious in their eating. During the first two days they got some cotton-wool from their bedding into their mouths, but this was inevitable. They often pecked at useless things or at conspicuous spots, such as a letter on a piece of paper, and so persistently at spots on the feeding saucer than one without spots had to be used, but they never swallowed anything injurious or useless. They would test particles of tobacco, for instance, with an exceedingly rapid touch, but they never went beyond testing. The same held good for young coots. One of the gulls, X, was tried repeatedly with a little twisted roll of paper ; he pecked at it three times after much provocation, but threw it away each time. On the positive side, it may be noted that they ate small worms in the garden and small insects without any hesitation the very first time. A noteworthy achievement was breaking a worm into pieces. A heavy meal of a particular sort seemed to be followed next day by repugnance to the same kind of food ; they showed that kind of repentance which is "the weight of undigested meals ate yesterday." Thus when Alpha and Beta ate too much fish on Friday they would not touch it on

Saturday, but partook of liver freely; and similarly with many other food-stuffs.

As to quickness of learning, the observation was made in regard to two young birds taken from the nest, who were having their first experience of food in a saucer, that the elder, after having some food given to it, proceeded to peck of itself, while the younger, who would at first peck only at the bill of its senior, began within five minutes to peck also out of the saucer.

As to words, the basis of experience was not sufficiently wide to bear secure conclusions, but there seemed to be at least four words. (*a*) There is the peep-peep uttered before birth, and also long afterwards when the birds are not quite comfortable. Sometimes in those artificially reared it would not be heard for fifteen minutes or more. It means cold, hunger, or some discomfort. (*b*) Secondly, there is a deeper, more adult-like quack of two syllables, uttered in excitement in the presence of food. (*c*) Thirdly, there is a short alarm cry, uttered when the bird is suddenly disturbed. (*b*) Fourthly, when the young bird appears to be contented and very comfortable, it utters a plaintive, almost sigh-like cheep.

One thing the gulls seemed to have to learn in their artificial environment was to recognise water to drink, but this may have been partly due to the fact that it was presented to them in a very unnatural way—in saucers, glass vessels, and shallow baths. Although thirsty, and willing to take a drop from the end of a wet finger, they would walk round, or even at first through, a saucer without using their opportunity. Like Lloyd Morgan's chicks, they drank when they got their bills wet *by happening to peck* while standing in water, and they also drank when thrown into water. Only after ten days' education did one go straight to a dish of water placed on the floor and

drink from it. An association was probably established between a shining surface and drink, for some gulls about three weeks old tried to drink from a glass lid removed from a pasteboard specimen box and placed on the floor.

Numerous little observations grew into a general impression that *the kin instinct* was strong, but it would be important to investigate this point carefully. There seemed to be, even from within the egg, a responsive piping to those outside, whereas Lloyd Morgan's artificially reared chicks paid no attention to the cluck of their mother —of whom they had no experience whatever—when she called from outside the door. A newly hatched gull, called Beth, tried on the first day to make towards Aleph in a separate compartment of the incubator; an older bird showed the greatest complaisance towards its younger companion, who followed it about and often tried to snuggle under its imperfect wing; when a novice about to have his first bath tumbled into the water, and screamed, being for a moment confused, his companion, who had experience of two previous baths, jumped in, swam to the novice, and touched him. When two strangers were brought together for convenience of warmth, there was in one case amity after a few bill-peckings, while in another case they were not seen nestling together till the third day. In two cases when a gull had taken flight into freedom, leaving a younger companion in the garden, the first to fly returned several times to visit the younger until it also flew. It was also interesting to notice that adults of the species flew about overhead when the young in the garden were approaching their time for flight. On the other hand, a herring gull which had been shot in the wing and lived in the garden displayed not the remotest interest in its small congeners. Nor were young coots interested in young gulls.

There seemed to be an instinctive following of one gull

by another, as is indeed common among birds. Indeed, to find one in a large room in the summer twilight, the quickest way was to set loose another. In confirmation of what has been remarked by Thorndike, it may be noted that one of the young gulls used to follow a little boy's bare feet persistently over the lawn, nestling beside them when he stood still.

Finally, it may be noticed that while there was for three or four weeks great tameness and familiarity on the part of the young gulls, the wild shyness and suspicion seemed to grow quickly after they were able to rise from the ground. The species is, of course, migratory, and there seemed to be a growing restlessness towards the end of July. But this may have been prompted by adults who occasionally flew round and round overhead. It was noteworthy, however, that there was a return of tameness on the part of a younger bird after the flight of its senior left it alone in the garden. It was once seen, for instance, to thread its way through a group of children squatted on the lawn, and coolly appropriate a strawberry from one of the plates.

THE PLASTICITY OF LIFE

IN his first *Law of Motion*, Newton stated that "Every body perseveres in its state of rest, or of uniform motion in a straight line, except in so far as it is compelled by forces to change that state." In this magnificent truism are summed up two aspects of Nature which are everywhere familiar to us—the tendency to persist in a given state or along a given path, and the liability to diverge under the action of incident forces. We may call the one the aspect of inertia, the other the aspect of change. Constancy, continuance, persistence, we see on the one hand; change, compromise, novelty, on the other.

Is it not true even of that complex which we call our personality? Our mental environment, our intellectual furniture, our ruling ideas—how they change for better or worse as we live; but beneath all there is a permanent element—a certain style of mental architecture, so to speak—which seems to change but little. The child, as we say, is father of the man.

The twofold impression of novelty and of persistence is familiar in history; periodically everything seems to become new, there are renaissances; on the other hand, history repeats itself; some of the trade-tricks of the Phœnicians or the banking-devices of ancient Babylon recur to-day, and we say, with a sigh, that there is nothing new under the sun.

We see the same two aspects in the history of that complex which we call our body. It is ceaselessly chang-

ing; it is always being un-made and re-made. We need not believe the rough guess of the old physiologists, who said that we were made all over again every seven years; but there is no doubt as to the ceaseless changes of breaking-down and building-up. In spite of all, however, the body does in great measure retain its integrity. The scrap of iron on the window-sill changes: it rusts; it becomes something else—oxide of iron. But the changes in the living body are for prolonged periods not incompatible with a certain permanence of character; the body retains its integrity. Chemically regarded, life is in great part a series of combustions; but we may say of the organism, "nec tamen consumebatur." There is a quality of persistent sameness.

This important idea has been well expressed by Huxley in his *Crayfish*, p. 84:—

"To put the matter in its most general shape, the body of the crayfish is a sort of focus to which certain material particles converge, in which they move for a time, and from which they are afterwards expelled in new combinations. The parallel between a whirlpool in a stream and a living being, which has been often drawn, is as just as it is striking. The whirlpool is permanent, but the particles of water which constitute it are incessantly changing. Those which enter it, on the one side, are whirled around and temporarily constitute a part of its individuality; and as they leave it on the other side, their places are made good by newcomers.

"Those who have seen the wonderful whirlpool, three miles below the Falls of Niagara, will not have forgotten the heaped-up wave which tumbles and tosses, a very embodiment of restless energy, where the swift stream hurrying from the Falls is compelled to make a sudden turn towards Lake Ontario. However changeful in the

contour of its crest, this wave has been visible, approximately in the same place, and with the same general form, for centuries past. Seen from a mile off, it would appear to be a stationary hillock of water. Viewed closely, it is a typical expression of the conflicting impulses generated by a swift rush of material particles.

"Now, with all our appliances, we cannot get within a good many miles, so to speak, of the crayfish. If we could, we should see that it was nothing but the constant form of a similar turmoil of material molecules which are constantly blowing into the animal on the one side, and streaming out on the other."

While we agree that the metaphor is just and striking, we feel that it has, like every other metaphor, its risks and limitations. As we have said in another place, "One may push the whirlpool metaphor too far, so as to give a false simplicity to the facts, for when vital whirlpools began to be, there also emerged what cannot be discerned in crystal or dewdrop—the will to live, a capacity of persistent experience, and the power of giving rise to other lives."

But what especially concerns us at present is, that our outlook on the animate world around us shows us at every turn the contrast which we have reiterated—the contrast between constancy and novelty, between continuity and new departures, between inertia and changefulness. On the one hand, there is the remarkable constancy between successive generations, the persistence of a specific average, the racial inertia ; on the other hand, there is the continual emergence of the new, the abundant crop of new departures, the racial mutability. Commonly, but not very accurately, the contrast is stated as that between heredity and variation. More accurately, it is the contrast between vital arrangements which tend to preserve an already established order, and others which provide the raw

materials for further progress, or it may be, of course, degeneracy.

When we realise how strong racial inertia is, and how literally we are chips of that old block which is the average of our stock, when we recognise that our inheritance is a mosaic of ancestral contributions, when we learn the inexorableness of what is called filial regression, which brings the children of unusually gifted or unusually ungifted parents towards the mean of the race, we are apt to become fatalistic. Therefore it is useful to illustrate, especially in the Spring, something of the other aspect of life—its plasticity. It must have been with some good reason that a sagacious thinker like Buckle depreciated the importance of heredity; the reason was his vivid impression of the power of nurture—surroundings and habits—in moulding character, both bodily and mental.

There is a well-known shore animal, *Lingula* by name, one of the lamp-shells or Brachiopods, which has been living in the world since the earliest ages (the Cambrian) of which we have fossil remains. Its direct ancestry is traceable for millions, probably several hundreds of millions, of years. It is literally a "living fossil." It flourished in the Cambrian ages, and flourishes very well still. It is so abundant to-day on some shores that its body is sold by the peck for food. Now the point of particular interest is, that this ultra-conservative animal has not changed all the time so far as we can tell from examination of the shell. There may have been internal changes in the soft parts, or there may not; we have no evidence. But as regards externals, *Lingula* has lived on for millions of years unchanged. It illustrates a remarkable hereditary constancy, sustained throughout a lapse of time which is so great that we cannot even vaguely imagine it. It is obvious that if all the living creatures we know had a story

like *Lingula,* appearing in the Cambrian and living on apparently unchanged until to-day, we should never have had any theory of organic evolution to puzzle over. We may regard *Lingula,* then, as the supreme instance of static racial inertia ; and it does not stand alone. But to judge of the history of animal life from cases like *Lingula* is, as has been said, like judging the flow of a river by a study of a small, quiet pool on its shore.

In contrast to the conservative *Lingula* we may take the common jellyfish (*Aurelia aurita*) as a good illustration of variability. It is constantly exhibiting variations, that is, inborn changes of germinal origin which result in the organism being different from the norm or average of its species. We know from the records of zoology that it has kept up this sporting for a great many years, though nothing seems to come of it after all. It is normally a tetrapartite animal, but sexpartite, pentapartite, and, more rarely, tripartite forms occur ; and the detailed variations are manifold. Similarly, whether we take pansies or poultry, wild animals or tame, we get the same impression of many a living creature as a Proteus. Whether we examine the vertebræ of sloths or the teeth of apes, the colour of dog-whelks or of guillemots' eggs, the external characters of land-snails or of ruffs, we have the big fact of variability staring us in the face. And whenever we begin to compare specimens with their "specific characters," which are only averages, whenever we take the trouble to measure and weigh, we discover that the fountain of organic change is more copious than even Darwin dreamed of. "Even Darwin himself," Wallace says, "did not realise how much and how universally wild species vary."

It is not to inherent variability, however, that the term plasticity refers, but to modifiability, to the capacity of being individually and directly changed in response to

changes in habits and surroundings. The changes which crop up in a brood of jellyfishes or in the progeny of an evening-primrose, seem to arise in the mysterious arcana of the germ-cells. They are born, not made; endogenous, not exogenous. Modifications, on the other hand, are novel responses to peculiarities in nurture; they are physiologically traceable to changes in environment or in function, and it is to them that our phrase, "plasticity of life," refers.

When an Englishman on foreign service becomes, in the course of half a lifetime of work under a tropical sun, so thoroughly tanned that the browning never disappears through all his years of pension-life in a Scottish Highland retreat—where the sun never scorches—we call that a "modification." It is a structural change in the body which transcends the limits of organic elasticity, and has been so saturating that it persists after the originally inducing causes have ceased to operate. We get clear of vagueness if we adopt some such definition, and it is to the capacity of undergoing such "modifications" that we wish to restrict the term *plasticity*.

Sun-burning does not happen to be of much practical importance, but it illustrates clearly what we mean by a bodily modification directly due to environmental change; just as the formation of callosities or hard skin pads on hands or feet may serve as an example of one which is rather due to change in function than to change in surroundings. What we wish to do is to show how broad a biological basis this doctrine of modifiability or plasticity has.

The fact that we wish to illustrate is the influence of the environment in producing modifications. "In a smithy we see a bar of hot iron being hammered into useful form. Around a great anvil are four smiths with their hammers. Each smites in his own fashion as the bar

passes under his grasp. The first hammer falls, and while the bar is still quivering like a living thing it receives another blow. This is repeated many times till the thing of use is perfected. By force of smiting one becomes a smith, and by dint of blows the bar of iron becomes an anchor. So is it with the organism. In its youth especially, it comes under the influence of Nature's hammers; it may become fitter for life, or it may be battered out of existence altogether" (*The Study of Animal Life*, p. 308).

It seems convenient to begin with a set of influences which may be associated together under the title *molar* or *mechanical*. We refer to pressures—lateral and vertical, to currents, to the action of gravity, to the amount of available space.

Many years ago, Professor Semper took a number of young freshwater snails (*Limnæa stagnalis*), apparently identical, and put them in different glass vessels, with the same kind of water, the same kind of food, and so on, the only known difference being that the volume varied. After two months it became plain that they were not getting on equally well; those in the vessels of large volume were growing apace, those in the small vessels were beginning to lag behind. As others have since done, Semper reared a series of dwarfs. Yung has also shown that the rate of growth of tadpoles bears some relation to the ratio of the amount of space to the number occupying it. Probably there was some other factor besides the amount of room, but there was no lack of food, air, or cleansing. In De Varigny's repetition of Semper's experiments the conclusion arrived at was, that the amount of exercise-ground at the top of the water was a very important factor.

The trend of the branches on a tree often shows the direction of the prevailing wind, and on some exposed parts of our coast the surface of the tree-tops in the wood slopes

gradually upwards, as if it had been pruned with a knife. The same sort of thing is seen in passive animals, such as sponges and corals. Of particular interest are cases where the same creature assumes quite different forms in different surroundings: thus it seems well proved that the huge Neptune's cup (*Poterion*) is the free form of a little shell-boring Clionid. Sometimes the environmental influences are hard to separate from influences of function: thus Camerano observed that tadpoles of *Rana muta* in swift streams had longer and larger tails than those in quiet pools near by.

A second set of environmental factors may be summed up under the general title, *chemical*, including the chemical composition of the surrounding air, water, soil, or other medium, including also the quality and quantity of the food. It may be fairly said that we are just beginning to appreciate something of the subtlety of relations between marine animals and the variable medium of sea-water in which they live.

By altering the salinity of the water, Schmankewitsch changed one variety of brine-shrimp (*Artemia salina*), in the course of generations, into another variety, and then reversed the process. It is very difficult to tell in many cases how far the structural change is the direct result of the environmental change, or how far the latter is only the liberating stimulus of the former—setting free some potentiality that was lying unexpressed in the egg or young creature. Let us take a few illustrations collected elsewhere.

"If the alkalinity of the sea-water be slightly altered, the egg of a sea-urchin allows itself to be fertilised by the sperm of a starfish, or of a crinoid, or of a mollusc (!), producing larvæ which all take after the mother. If the chemical and physical state of the sea-water be slightly

disturbed, artificial parthenogenesis can be induced in starfish and sea-urchin, in worm and mollusc. Sometimes the result of a slight chemical change is very perplexing, and there are many experiments at which we look with bated breath. Quaint abnormal larvæ of sea-urchin and frog are obtained by adding a *little* lithium salt to the water, and the addition of a pinch of magnesium salt to the sea-water containing embryos of the fish *Fundulus heteroclitus* induces in a large number of these the development of a single Cyclopean eye in place of the normal two eyes. A small Crustacean called Gammarus, very common in fresh water, has the habit of avoiding the light, but add a little acid so that the solution is no stronger than $\frac{72}{1000}$th of 1 per cent., and Gammarus swims towards the light. Remove one or two of the metals from sea-water, keeping up the alkalinity, and the sea-urchin's eggs all develop into twins."

The changes that may be brought about by altering the qualities and quantity of the food are so numerous and important, that we cannot wonder at Claude Bernard's saying that evolution was throughout a function of nutrition, or at the prominence which some sociologists give to diet as a factor in human evolution. Although Moleschott's aphorism, "Der Mensch ist was er isst," seems to over-shoot the mark, the nutritive factor is one of the strongest. Here again we must distinguish between a directly modifying effect and the liberation of a latent character. When we change the colour of canaries and parrots by changing their diet, that seems to be a direct effect; but it is probable that the abundant and rich food given to the queen-grubs in the beehive is not more than liberating stimulus. Marchal reports that a scale-insect (*Lecanium corni*) becomes another species (*Lecanium robiniarum*) when reared on *Robinia pseudoacacia* instead

of on its own normal food-plant, though the reverse experiment does not succeed. Every one knows how extraordinarily plants change in different soils, or under the influence of manure, and it is to be suspected that some of the hundreds of new parasitic worms that are continually being described from new hosts are really old acquaintances modified by a slightly different nutritive environment. This suggests a line of experiment that is sure to lead to interesting results.

A third group of environmental influences is that of the *physical energies*—heat, light, and electricity. Heat chiefly affects the rate of growth, promoting the formation of nuclein-substances, and thus inducing cell-divisions. A minute Infusorian (*Stylonichia*) studied by Maupas was seen to divide once a day at a temperature of 7° to 10° C., twice at 10° to 15°, thrice at 15° to 20°, four times at 20° to 24°, and five times at 24° to 27° C. . . . It is probably for this fundamental reason that some molluscs are twice as large in the Tropics as they are in Europe. In general, we may say that increased warmth hastens growth and development: in some cases it favours reproductivity, especially of an asexual sort. The green-flies or Aphides multiply prodigiously and parthenogenetically on our rose-bushes and pear-trees in summer months, under the combined influence of food and warmth; when food becomes scarcer and the weather colder in autumn, males are born, parthenogenesis ceases, ordinary sexual reproduction recurs.

Cold retards growth and development. Thus Camerano found that tadpoles of *Rana muta* remained tadpoles for three or four years, when kept at a low temperature. The period of development of the North Sea herring may be doubled (extended to fifty days or more) by cooling the water. The puzzle that the population of floating and drifting marine animals is denser in the Arctic waters than

in the Tropics, is perhaps explained by one of Professor Loeb's experiments, which showed that lowering the temperature greatly increases the length of life of small crustaceans. So in the cold waters there are more generations living at the same time than there are in the Tropics.

As in other cases, it is difficult to distinguish the direct physiological effect of a change of temperature from the indirect effect due to the liberation of what is latent. Lowering the temperature of the caterpillar box may be followed by curious aberrations of colour in the moths and butterflies, especially in the direction of darkening (melanism). If the vessel containing some sea-urchin's eggs in sea-water be placed near the stove for a short time, a large proportion of them may form twins!

Light has subtle influences of many kinds, often illustrated by changes in coloration. Professor Poulton has proved that the surrounding colour influences the colour of caterpillars and pupæ, apparently operating indirectly through the nervous system. He showed, for instance, that the caterpillars of the small tortoise-shell are for a short time so sensitive, that those in a white or gilded box have light or golden pupæ, while those from a dark box have dark pupæ.

In the case of young flat fishes, such as soles and flounders, light is the necessary stimulus for pigment-formation, and the down-turned shaded side remains unpigmented. Mr. J. T. Cunningham made the beautiful experiment of placing a mirror on the floor of a tank where young flounders were undergoing their gradual metamorphosis from symmetrical into asymmetrical forms. Out of thirteen young flounders whose under-sides were thus illumined by a mirror for about four months, only three failed to develop black and yellow colour-cells on the skin of the down-turned side, which normally remains white.

In the fourth place we may recognise a group of influences, much larger than might be supposed at first sight: those which one living creature may exert upon another by contact, pressure, irritation, poisoning, parasitism, and so on. We may refer, for instance, to the hundreds of different kinds of galls which are produced on plants as reactions to a variety of stimuli, usually the salivary secretions of the larvæ of small Hymenoptera and Diptera that have hatched within the leaf or twig. Or we may mention the strange effects that follow the establishment of the Sacculina parasite in a crab, and the deformations that are due to other parasites. The pearls found in various bivalves seem to be the beautiful sepulchres of larval tapeworms or flukes, which the skin of the mollusc smothers in layer after layer of translucent lime.

We have given only a few instances of modifiability—one of the fundamental facts of the Biology of the Seasons—but perhaps enough has been said to serve as a basis for further study. Certain general results stand out.

It is noteworthy that young creatures, such as caterpillars and tadpoles, are far more modifiable than adults. The reasons for this plasticity of youth are not far to seek: the young and growing organism is less "set"; it is still arranging itself internally in many of its parts; it has not quite settled down; it is more susceptible and less embarrassed. There seems almost no limit to the tricks that may be played with tadpoles. Large portions may be removed without apparent detriment, part of one may be grafted on to another, their growth may be quickened or slowed, and they may be kept for years from becoming frogs at all.

All of this has its suggestiveness in reference to human kind. We cannot hope to make a silk purse out of a sow's ear, or tares into wheat, or bricks without straw, because

of the inexorability of inheritance; but we can, by judicious changes in surroundings and habits, modify the individual very much for the better, especially if we begin early enough.

If we are to think clearly of modifiability, we must distinguish not only between inborn variations and acquired modifications, but between direct modifications and the secondary results of these, *i.e.* between direct modifications and those changes to which the environmental change was only the liberating stimulus—pulling the trigger that allowed a latent character to find expression. We must also admit the possibility—the discovery of which is one of the most progressive steps in modern evolutionistic experiment—that an environmental change may affect the next generation *without* affecting the present one. Professor Tower of Chicago worked for a dozen years on beetles of the genus *Leptinotarsa*, which he subjected to unusual conditions of temperature and moisture when the male or female reproductive organs were at a certain stage in their development. The result was to induce in the offspring striking changes in colour and markings, and also in some details of structure. Sometimes all the germ-cells seemed to be affected, sometimes only a fraction of them; sometimes various changes resulted from the same treatment; some of the changes were brusque, others showed intergrades with the parental conditions; sometimes the changes did not occur until after the lapse of several generations in the unusual environment. It is obvious, of course, that the experimenter could only influence the reproductive cells *through* the body of the parent, but the important point is that the body of the parent was not affected. Here, in other words, we have definite evidence of germinal variation evoked by environmental stimulus.

There are several similar sets of facts in regard to plants, and their elaboration is one of the most urgent and promising of evolutionist inquiries. It is probable that we are here on the track of discovering what may be called *external variational stimuli*, and it may be that along this line of experiment will be found an interpretation of some cases suggestive of the transmission of modifications, which is, for many reasons, highly improbable and, in any case, unproved. It gives a fresh interest to the seasonal outlook, too, to reflect that this complex and changeful environment, through which so many plants and animals, in spite of all that we have said of their modifiability, pass callously and unaffected, may yet be not without its influence on generations yet unborn.

All naturalists are agreed in admitting that modifications are very common, that they are of much individual importance, that they may have an indirect influence through the parent's body on the offspring (especially in the case of mammalian mothers), and that they may have in various ways an indirect importance in evolution; but there is less agreement as to the answer to be given to the following much-debated and often misunderstood question: Does a structural change in the body, induced by change of function, or by change in surroundings and nurture generally, ever influence the germ-plasm in the reproductive organs in such a specific or representative way that the offspring will thereby exhibit the same modification that the parent acquired, or even a tendency towards it? For our part, we do not know of any clear case which would at present warrant the assertion that a bodily modification is ever transmitted from parent to offspring.

What is certain, however, is that the plasticity of the living creature admits of definite modifications being

reimpressed on successive generations of individuals, and a number of evolutionists (Mark Baldwin, Lloyd Morgan, Osborn, and James Ward) have pointed out that modifications may thus serve as screens until coincident variations (similar in appearance, though intrinsic—not extrinsic—in origin, and with a greater grip) can emerge and establish themselves.

Suppose, for a moment, that there was an island where swarthiness of skin became, through climatic changes, absolutely essential to success in life. Suppose that a large proportion of the population became so tanned that they met the critical test and survived—survived in virtue of plasticity or modifiability. They would be in great difficulties in regard to their children, awaiting the anxious day when it would become plain that their children were also plastic or modifiable in the direction of sun-burning. Suppose, however, that meanwhile there was a widespread constitutional tendency to swarthiness, suppose that more and more innately swarthy children were born, does it not seem extremely probable that the unentailed, purely modificational swarthiness might act as a protective screen, fostering the innate entailed swarthiness?

To sum up, then, in a statement that will apply to ourselves as well as to the plants and animals around us: The complex environment produces modifications, which are often very important to the individual, and may also be of indirect importance in the evolution of the race; it also supplies the appropriate nurture (in the widest sense), without which the inheritance cannot express itself; and it probably affords—though we know little of this as yet—a succession of stimuli, provoking some of those germinal variations which form the raw material of organic progress.

ADOLESCENCE

IT is impossible to refrain from continuing the line of thought from the adolescence of animals to that of man, but in so doing we must admit that there are great differences. We have to remember that man is by nature on a higher platform than that occupied by any of the animals—a platform marked by language, reason, and morality. We have also to remember that the human environment differs very markedly from that of animals, because of the rich external heritage expressed in social institutions, historical records, literature, art, and so on. Therefore, one should be very careful in carrying into a discussion of human problems the conclusions that have been reached by a study of animal life.

This cautious position is obviously sound, but it is apt to become obscurantist. For it must not be forgotten that there is an all-pervading unity among animal organisms, *including men*; there is essential similarity in structure, in everyday functions, in manner of development, in the nature of growth, in the punctuation of life, in the fundamental springs of conduct, and so on. It is therefore to be expected that a study of animal life—embryonic, young, adolescent, mature, and old—will have some light to throw on human infancy, childhood, adolescence, maturity, and old age. At the same time, it is a commonplace of scientific method that every conclusion formulated in regard to a particular order of facts—let us say the behaviour of birds—

must be *tested afresh* when applied to another order of facts, such as human conduct.

Returning to our figure of an ascending and a descending curve, we see that the period of human adolescence is an ill-defined part of the up-grade—after juvenile characters have been for the most part lost, when adult characters are being put on, when childish ways and childish things are being put away and the life is taking definitive shape, when sex-impulses begin to be more than whispers and the limit of growth is within sight.

Our first note relates to the difficult question of growth. From studies on animals it seems clear that growing is an uphill business; it is an ascent whose gradient becomes always steeper and more difficult. It illustrates what is called the law of diminishing return. At the same time, though the juvenile rate of growth is never afterwards attained, and in most cases is not even approached, there is often a remarkable reacceleration during adolescence. Like a good horse, the organism puts on a spurt as it gets near the top of the hill.

Professor C. S. Minot compares the business of growing to the building of a wall by one man. As the wall rises, the man becomes more and more tired; he has to lift the stones higher; he builds more and more slowly. The wall goes on growing, but at a steadily diminishing rate. We may say, perhaps, that just as he gets near his limit, beyond which he cannot reach, he braces himself up for a rapid effort.

Now, there is a corresponding acceleration associated with human adolescence, and we do well to remember it, for it means that the energies of the organism are necessarily to some extent preoccupied with its own business. It is an intricate and difficult problem: there is increasing stability and increasing instability, there is great vigour

and great "slackness"; but the general statement seems to us to be safe, that a rapidly growing adolescent is naturally a good deal preoccupied—we mean, of course, *organically, not consciously,* preoccupied—with his or her internal affairs. This means that he or she should have plenty of rest and plenty of play.

Our second note concerns internal rearrangements. If we take a wide survey of adolescent animals, and mark the beginning of the adolescent period by the assumption of definitely adult characters and the laying aside of distinctively juvenile characters, then we must include in our conception of adolescence the idea of internal change, rearrangement, and readjustment. There is often among animals a well-marked *juvenile* period, as we have seen, as of caterpillars or of tadpoles, of kittens or of chicks; there is often a well-marked *adult* or *mature* period, of butterflies or of frogs, of cats or of hens; between the two lies the ill-defined *adolescent* period, the biological hobble-de-hoy phase, when the creature is neither juvenile nor adult, but between the two. In this period there are often readjustments and new adaptations. There may be increase of complexity (differentiation) or the establishment of more perfect unity (integration)—the two criteria of all organic progress, whether individual or racial. The adolescent creature is more complex than it was—from its teeth to its nerve-paths; it shows the structural results of increased division of labour; it differs from its juvenile phase as the locomotive of 1910 differs from Stephenson's "Puffing Billy." But it also becomes more controlled, unified, harmonious, more vertebrated and knit together; its character becomes set; it gets a purpose in life. From its plastic juvenile stage—often so delightfully irresponsible—it differs in integration, just as the locomotive of 1910 differs from "Puffing Billy."

It seems useful, therefore, to turn on the biological light in considering the human facts, which are, in a way, too near us to be fully appreciated. Let us think vividly of the transition-period between tadpole and frog, between caterpillar and butterfly, and so on, and take back again to human life the impression of re-differentiations and reintegrations (that is, of new complexities and of new controls), of inflammatory crises and of losses that mean gains. For thus we begin to understand better why adolescence is so full of portent as well as promise.

A third fact which lends further importance to adolescence is that it extends over the momentous, critical time when decision is given in regard to the individual variations which crop up during the juvenile period. We have seen that each young thing is an original, that a child is always leading the race, that it is in youth that the fountain of unrealised capacity wells up. We have still to consider, following Groos and others, the biological importance of the play-period, when inborn variations have elbow-room, when new departures have a chance, when there is an opportunity for originality to gain self-confidence, for a new pattern of personality to gain some stability. Every one knows that man, like other domesticated creatures, has strong play instincts.

But on the heels of the period in which play instincts find—or should find—full and free expression comes the adolescent period, during which the conditions of the struggle for existence, the rules of the serious game of life, all sorts of restrictions and conventions, from the law of the jungle to the etiquette of social behaviour, begin to close in upon the individualities, the idiosyncrasies, the peculiarities, in a word, the *variations* of the young life. The organism must run the gauntlet of criticism, and often

it needs it much, if it is to survive well or survive at all. On the other hand, the criticism, whether of circumstances or of society, does not always make for progress, and many fine buds are probably killed or spoilt. While it may be impossible to lay down general rules for human adolescents, the important thing is that we realise clearly what is happening. And since freshness is rare and monotony common, it seems a wise rule that our judgments should lean to mercy's side. Running the gauntlet may be necessary, but let us be sparing with those heavy-handed snubs which are so fatal to the growth of the saving grace of originality.

In the fourth place, we may profitably link together the two concepts of adolescence and plasticity. We have seen that one of the biological certainties in regard to young creatures is their plasticity in receiving modifications from their surroundings. By modifications, as explained, we mean changes due to peculiarities of nurture—changes neither inherited nor transmissible, so far as we know. Now, great modifiability, as seen in caterpillars and tadpoles, for instance, is characteristic of youth, and it is often during the adolescent period that decision is given whether a piece of juvenile veneer is to persist or not. Undesirable youthful veneer is often slipped off; effective veneer is often confirmed. When youthful modifications, for good or ill, survive the adolescent period, the chances are that they will persist throughout life.

In the fifth place, much of the biological importance of adolescence is bound up with the central fact that it is the period in which the promptings of sex-impulses first make themselves normally assertive. In various ways—for instance, by the liberation of chemical excitants (or hormones), which saturate through and through the body—the sex-impulses influence the whole being, transforming it not

only externally, but in its inmost recesses. The transformation may be almost violent—in man as in beast, especially in the male sex—or it may be as gentle as the coming of Spring.

The change is often a new beginning of life—it is to be allowed for and respected. It should be seen in its biological setting—as part of a world-wide process—yet it is not to be hastily materialised. It should be seen in an evolutionary light, in line with the evolution of love in the animal kingdom. It may humble us at times to recognise that adolescent experience in mankind is in some measure bound to be recapitulative, but it will always make us hopeful to feel that it is part and parcel of a great evolutionary movement, sharing in the phylogenetic ascent from crude expressions of physical fondness to what we must, in some sense, call spiritual affection.

Considering the profound importance of the subject, we may be pardoned for going a step further—recalling the main thesis of an important paper by Mr. James Oliphant in the *International Journal of Ethics*, in which it is pointed out that in the course of civilisation there has been established a sane tradition which sublimes sexuality by associating it with the best that is in us—chivalry, devotion, self-control, worship. Unconsciously, for its own preservation, humanity has idealised the sexual-impulse, has detected its true inwardness, has linked passion to fine feeling. In literature and art the ideal types of love in its sublimest aspects have been immortalised, and with these the minds of those who rejoice in their youth should be filled, not as an artifice, but because thus a deeper meaning and joy may be found. To fail duly to honour the sexual-instinct means forcing it back in isolation as an animal passion, whereas the lesson to be learned, until it become

organic, is to associate physical passion with the higher emotions — to bind the insistent organic impulses into unity with pride of flesh, pride of birth, a high standard of cleanness and fitness, an honour of women, a love of children, and a social self-respect.

THE PLAY OF ANIMALS

ONE of the most important indirect results of Darwinism has been to convince naturalists that no fact of life is trivial. To the inquisitive spirit everything is a problem; but the problem is illumined when we realise, as Bagehot put it, that "everything is an antiquity"—the product of a past often inconceivably long, an event, a personage, or, it may be, only a "property" in the drama of evolution which has filled the world-stage for millions of years. Moreover, it was part of Darwin's genius that he realised, more than any other, the solidarity of Nature and the interrelations of things. The *Systema Naturæ* was the crowning work of Linnæus; but it was a new system of Nature that Darwin disclosed—a web of life—in which even the apparently trivial fact is invested with momentous importance because of its complex correlations with others. A moth, escaping from an entomologist's window, is said to have cost the United States a million of dollars; a few sparrows and rabbits, transported from their native home, disturb the balance of life in two continents. The clay-clodlet on a bird's foot may affect the fauna and flora of a district.

Similarly, play—whether of animals or of men—which would have been regarded by most pre-Darwinian naturalists as a trivial thing—a sort of aside in Nature—has been shown by Professor Groos to be of fundamental importance. Let us see how this works out.

We need not spend time over any definition of play—that comes last, not first. We see it all around us in the

Spring-time, and we all have vivid reminiscences or present experience of what it means. It is, to say the least, very widespread among mankind, though one reads in Mr. Kearton's entertaining book, *With Nature and a Camera*, the following sentences in regard to the people of St. Kilda: "I innocently asked the minister one day what kind of games the children played. The old man smiled good-naturedly at my ignorance, and answered: 'None whatever; their parents would consider it frivolity to have them taught anything except climbing rocks, catching sheep, and such other things as will become necessary to them in after-life.'" Now, while we do not go the length of placing play quite in the foreground of life, or of accepting a brilliant artist's description of life as "a series of interruptions from golf," we believe that Groos is right in his thesis that play is fundamentally important. There are, as we shall see, strong biological reasons for believing that the good people of St. Kilda would increase their present and future effectiveness, as well as happiness, if they let the children play. That would probably do more than increased postal communication to put aside "life-harming heaviness."

When we watch the kittens with their ball, the dogs and their sham-hunt, the lambs and their races, the monkeys and their "tig," we get a vivid impression of play. We may say, *negatively*, that play is not work, though it may be as strenuous; that play is not mere exercise, though, perhaps, it exercises best; that play has no seriously perceived or conceived end for the sake of which it is played, though it may be, while it lasts, most serious; that it is not necessarily social, for many an animal (like many a man) seems to be quite happy playing alone; and that it is not necessarily competitive, though that often gives zest to it. Of its positive content, we shall speak later. For

purposes of clearness, we shall leave out of consideration at present anything that might be interpreted as love-play or courting-play, and keep mainly to the play of young animals.

There are two main theories as to the play of young animals, and the first is that play is an expression of overflowing vigour, energy, and animal spirits; that it is the byplay of vigour. This view was first clearly stated by Schiller; it was long afterwards elaborated by Herbert Spencer—a strange contrast of champions.

This theory is simple; but it is too simple, and it breaks down badly. No doubt the young creature is an overflowing well of energy; but even the tired animal or child will turn in a moment from fatigue to play. Moreover, the theory does not in the least explain the *characteristic forms* of play in different animals. In fact, the theory only states one of the internal or physiological conditions of play—there must be some energy to spare.

Schiller's theory of play was re-expressed, as we have said, by Herbert Spencer; but he, feeling its inadequacy, eked it out by laying emphasis on *imitation*. The cause, he said, is superfluous energy; imitation defines the channel of expression. The youngsters mimic in play what they see their seniors doing in earnest.

This is a favourite theory, and there is a strong element of truth in it. That it cannot be the whole truth seems to have been shown experimentally. A kitten taken very early from the mother will play profusely without any known possibility of imitative stimulus.

The second theory of play is Darwinian, and Groos has the credit of having developed it. According to this theory, there are inborn play-instincts, characteristic in form for different types. They may be stimulated by superfluous energy and influenced by imitation, but they

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are in their essence instinctive. These play-instincts arose like other innate idiosyncrasies (by germinal variation), and they have been gradually established and strengthened by the consistent elimination of the bad players (in subsequent life-struggle).

But why should there be elimination of the bad players? Because play is justified in the business of life in at least two ways; firstly, because it is the apprenticeship to future work, the training for serious efforts, the rehearsal before the real performance; and, secondly, because intellectual development probably flourishes better in proportion as the brain is freed from the necessity of bearing with it the hereditary mechanism for the perfect performance of certain activities. If play can perfect any instinctive activity before failure is vital, the weight of a stereotyped inheritance is lessened.

But we may go a step further. Play is more than the apprenticeship, the rehearsal, introductory to future life and work. It is more than a means whereby the brain may be freed from some of its hereditary burden, and thus left more "educable." It is one of the few opportunities which afford free scope for variations without too rigorous selection. This is of very great importance as regards the practical outlook of man, and perhaps also as regards art, and we need hardly say that it has been an important factor in the intellectual evolution of animals. In the real business of life, most initiatives—"new departures," "idiosyncrasies," "variations"—are subject to rigorous selection, which often nips them in the bud. Play is Nature's device for granting temporary elbow-room for variations, some of which may form part of the raw materials of progress.

There seem to be two fundamental and primitive forms of animal play—the play of movement, and the

play of experiment. Let us, first of all, consider play of movement.

"Most young things," Hamerton says, "appear to be reservoirs of pent-up natural energy that finds vent in irrepressible gambols." But this takes specific forms in different cases. Insects gambol in the air, birds among the boughs, dolphins in the waves, and so on, endlessly—each in its own way. There is no use in it, except that the nerves and muscles are trained for future work. The heart beats more quickly, the breathing is more rapid, the peripheral blood-vessels expand, and there ensues that happiness which is the reflex of healthy function.

Perhaps part of the significance of this simplest form of play is to be found in the connection between pleasant emotion and muscular movements. Such exuberance of good spirits had the simple wood-chopper portrayed in Thoreau's *Walden*, that when a thing amused him, "he sometimes tumbled down and rolled on the ground with laughter," and perhaps we have here an expression of primitive playfulness.

When we see beautiful sights, or hear fine sounds, or the like, sensory impressions have, of course, travelled into our brains. But they do not, so to speak, stop there. They set agoing other messages, which travel out to the heart, which beats differently; to the larynx, which vibrates; to the lungs even, and to other parts. In short, internal muscular movements occur. As the result of these, a third set of messages travel in again to the brain; and when the circle is completed, *we are pleased*. Perhaps in this way one gets nearer an understanding of certain gambols and of the vocal play—the song—of birds. The latter seems to be due to internal muscular movements associated with strong emotions. In any case, there is reason to believe in a deep and subtle connection between

emotion and motion. Literally, Wordsworth's heart leaped up when he beheld a rainbow in the sky, and filled with pleasure as he watched the dancing daffodils.

The play-nature of animal movements is most obvious when there is something unusual about them. Thus Alix relates that on one occasion, when botanising on the Alps, his dog ceased to follow him on the gradual path, and seemed deliberately to choose a long slope of frozen snow. There he lay down on his back, folded his legs, and slid down like a toboggan. At the foot he rose quietly, looked up to his astonished master, and wagged his tail. Alix imagined that his dog had thought out the short-cut; it is much more likely that it was simply play—done for fun.

All movements that can be shown to have direct utility must, of course, be excluded from the category of play; but a number of cases seem well substantiated. When Romanes says of fishes, "nothing can well be more expressive of sportive glee than many of their movements," we feel that the statement is too general and vague; but it is difficult not to admit the genuineness of the movement play of Macropods and of Sea-Horses. When Hudson says, "I have spoken of the firefly's *pastimes* advisedly, for I have really never been able to detect it doing anything in the evening beyond flitting aimlessly about, like house-flies in a room, hovering and revolving in company by the hour, apparently for amusement," we feel the difficulty of excluding some undiscovered utility; but when we watch monkeys on their swings, we feel that, if we are not to make Nature magical, these *are* plays, and nothing else.

Let us pass to the other simple and primitive expression of the play-instinct, what we may call experimenting—when animals test things, often pulling them to pieces; or test themselves, often performing interesting feats; or test their neighbours, finding out how they will respond.

For the endless task of finding out about the world has its play-form—which is obviously one of the roots of science.

Speaking of his young goats, Mr. Hamerton says: "If there is a basket in the place which will hold one of them, and no more, the others will watch him with great interest, and as soon as he jumps out (which he is never very long in doing) the others inevitably jump in and out again by turns. A game of this kind will last till one of the kids has a new suggestion to make."

One day it was the fashion among the kids to carry a little sprig of green between the lips; another day they tried to upset the artist by getting under his seat; from that they passed to experimenting with the big dog, till "he could stand it no longer and rushed out of the place, not trusting himself to refrain from using his mighty jaws, which would have crushed a kid's head like a nutshell."

As one sees, it is extremely difficult not to intermingle inference with observation; but there are some very careful records bearing on the play of experiment. Thus we may quote a few sentences from Miss Romanes' observations on her Capuchin monkey—a very valuable and well-executed piece of work: "He is very fond of upsetting things, but he always takes great care that they do not fall upon himself. Thus, he will pull a chair towards him till it is almost overbalanced; then he intently fixes his eyes on the top bar of the back, and, as he sees it coming over his way, darts from underneath, and watches the fall with great delight; and similarly with heavier things. There is a wash-hand-stand, for example, which he has upset several times, and always without hurting himself. One day he played for a long time with a hearth-brush, learning to unscrew the handle and, what was much more difficult, putting it together again. When he had become by practice tolerably perfect in screwing and unscrewing, he

gave it up and took to some other amusement. One remarkable thing is that he should take so much trouble to do that which is of no material benefit to him." This last remark is interesting, though it should have been expressed differently. It is part of the essence of play that it is not of direct material benefit.

Passing from gambol and experiment to somewhat more evolved forms of play, we find that a number of animal games may be summed up under the title "sham-hunt." Into this there seems to enter a psychological element of self-illusion. The booty may be real, as when the cat plays with the mouse, or both the booty and the chase may be fictitious. The sham booty may be living, as when the dog plays with a beetle, or, more commonly, not living, as when the kitten plays with a ball of twine.

Many naturalists have written concerning the play of a cat with the mouse. It has been interpreted as a whetting of the cat's appetite, as a means of improving the flavour of the mouse, and as elaborate cruelty. Romanes, though a man of keen insight, committed himself to the view that it illustrates the delight in torture. Probably these suggestions are all unnecessary. Surely, what we see is just a little game, justified in the present by the repetition of pleasant excitement, justified in the future by the increased dexterity which it develops. When exhibited by cats of mature years, it is perhaps just a relapse into a favourite game of youth—and analogues of this may be found among men. It must be remembered that a great many carnivores play just as the cat does. Their play is a practice for their work.

Another type of play is the sham-fight, which we see so often between puppies or kittens. It has been described among lions, tigers, hyænas, wolves, foxes, bears, and other carnivores; among lambs, kids, calves, foals, and other

ungulates; it is also very common among birds. Care must be taken to distinguish sham-fights from real fights, and it may be admitted that among animals, just as among boys, what begins in fun may readily pass into deadly earnest. In a vivid description of the behaviour of two young gluttons, Brehm says that nothing could be more playful, they are almost never at rest for a minute, they fight in fun all day, but every now and then the note of earnest is struck.

Of much interest, considering the level at which they occur, are the sham-fights of some ants. Near the beginning of the nineteenth century, Huber related that on fine days the meadow-ants collect outside the ant-hill and hold sports, especially of a wrestling and gymnastic sort. For a long time this story was rather scoffed at, and we cannot wonder; but in 1874 Forel saw the same sight, confessing at the same time that he should not have believed it unless he had seen. The ants behaved like a crowd of schoolboys riotous with fun—scrambling, wrestling, jumping, and fighting. "Yet all," he says, "was without anger and without any squirting of poison; it was plainly a friendly tournament." Fun seemed to be uppermost, but it is possible that the apparent play might be a sort of exercise or drill. It is also possible that the whole business was misinterpreted, for it is notoriously difficult to get mentally near animals in which instinctive behaviour is dominant.

The sham-fight is one of a large group of social plays, of which the characteristic note is rivalry—rivalry, however, which has no serious reference to any material object of desire. There is no doubt that the competitive element gives zest to animal games as well as to those of man. It is not essential, but it is an important auxiliary. It seems to be a pleasure to the animal as to us "*to be a cause*"; it is a

greater pleasure to be a more effective cause than some one else. We may refer to the races among lambs and kids, wild horses, and asses; the various forms of "tig" and "follow my leader" in monkeys; and to other rival exhibitions of agility. Perhaps some forms of dance and song should be included here, when they occur unconnected with courtship. And even when they have some connection with courtship, it is difficult to decide whether the courtship led to the play, or whether a form of play was utilised in the courtship.

We may give one instance of the kind of competitive display to which we refer, taking Mr. Hudson's description of the cock-of-the rock (*Rupicola*) of tropical South America. "A mossy level spot of earth surrounded by bushes is selected for a dancing-place, and kept well cleared of sticks and stones; round this area the birds assemble, when a cock-bird, with vivid orange-scarlet crest and plumage, steps into it and, with spreading wings and tail, begins a series of movements as if dancing a minuet; finally, carried away with excitement, he leaps and gyrates in the most astonishing manner, until, becoming exhausted, he retires and another bird takes his place." There are similar displays among uncivilised races of men to-day.

To sum up: There are many play-instincts among animals; they have been wrought out in the course of ages, partly as safety-valves for overflowing energy, partly as the muscular correlates of emotion, partly as opportunities for the emergence of variations before too rigorous selection begins, but mainly as periods for educating powers which are essential in after-life. Animals, Groos says, do not simply play because they are young; they continue young in order that they may play.

In short, play is so widespread because of its fundamental importance as *the young form of work*. The animals

who played best when young, worked best, lived best, perhaps loved best when they grew up, and thus through the long ages the play-instinct has been fostered. It is interesting, also, to notice that the animals which man has succeeded in domesticating are notably playing animals.

If Groos's theory of animal play is biologically sound, as it seems to us to be, it must apply also to human-kind. Children's games are natural safety-valves, to close which must mean disaster; they are opportunities for the free play of individuality, originality, idiosyncrasy—variations, in short, more or less sheltered from selection; they are necessary to the perfecting of powers—physical, emotional, and intellectual—which are afterwards of critical moment. Play is thus a rehearsal without responsibilities, a preliminary canter before the real race, a sham-fight before the real battle, a joyous apprenticeship to the business of life. Thus our study of animals playing in the Summer sunshine gives a deeper meaning to the familiar saying, "All work and no play makes Jack a dull boy." May we not twist an old precept a little, and say, "Let us play while we can, so that we may work when we will"?

THE DUST OF THE AIR

ONE of the flies in the ointment of Summer is the dust. It blinds and chokes us, making the highway journey a penance; it disfigures the hedgerows and spreads into the meadows. Sometimes it rises in beautiful swirling pillars which glide like wraiths along the road; but, except at a distance, dust is an abomination, and in many parts of the world it is a terror. In the present transition age of means of locomotion it is distressing to see how the dust raised by automobiles has ruined beautiful wayside gardens; let us hope, however, that just because of motor-cars we shall eventually have less road-dust than ever.

"Except at a distance," we said, for it is well known that dust plays a very important rôle in making the world beautiful, and it is well to consider this side of it. The fundamental investigations, we believe, were those made a good many years ago now by Dr. John Aitken, who first explained clearly the making of mist and the secret of fog. Mist is a concentration of moisture round the dust particles of the air, which are carried up from the earth's surface by currents, by evaporation, and by volcanic action, or are due to meteorites. Fog, in the same way, was shown by Aitken to gather round the same minute foci; and even the raindrops have their black hearts. It is interesting to look with a strong lens at the minute motes formed on the well-cleaned glass-cover of a museum case during a foggy day; one sees that an almost microscopic drop has fallen

and dried, leaving a circular mark with a dust particle in the centre.

Mist, fog, cloud, and rain thus consist of more or less wet dust-particles of great fineness; or, to say the same thing once again, fog is dust-dew. Familiar facts now, but surely not without a certain poetry.

Aitken was led to a clever contrivance for actually counting the myriad atomies of dust which play so important a part in making that curious mixture which we call weather. The device was to make rain in the air, and then count the drops. A measured sample of the surrounding atmosphere is drawn into a receiver, where it is diluted with a certain quantity of dustless air, and then saturated with water. By a stroke or two of an air-pump, it is expanded and chilled till the water vapour and the dust fall together in a mimic shower of raindrops on a polished plate.

When the miniature shower is over, that is to say, when all the dust has fallen, the number of drops on a measured area of this plate is carefully observed, and as each drop has a dust particle in its heart, it is possible in this way to count the motes which seem so incalculably numerous as they "dance" on the path of a "beam of light."

By this simple apparatus for making rain and counting motes, Dr. Aitken was able to gauge the quality of the air in all sorts of places and conditions, and his method or some modification of it is now in everyday use in Public Health Departments and the like. We must be content to give a few illustrative instances of this sampling. In the lecture-room of the Royal Society of Edinburgh, before one of the meetings, the air near the floor showed 275,000 dust-particles in a cubic centimetre, but after the lapse of an hour and three-quarters of meeting the scientific atmosphere showed 400,000. Of obvious importance in connec-

tion with less efficiently ventilated rooms, is the immense increase in the number of dust-particles after the gas is lighted of an evening. More sensational, perhaps, is the fact that a cigarette smoker sends 4,000,000,000 particles, more or less, into the air with every puff.

Of great biological importance is the contrast between the freshness of the country and the dustiness of towns. One clear day at Colmonell in Ayrshire there were only 500 particles (about the minimum) per cubic centimetre, or 8200 per cubic inch, while on a wet morning near the Central Station in Glasgow there were 466,000 per cubic centimetre, or 7,642,400 per cubic inch. The brilliancy of Swiss air is due to the comparative scarcity of dust, while the dismal fogs of our large cities are due to its abundance. The more dust-particles, in short, the murkier the air, and what we call haze is often little more than dust. The botanists tell us of plants which are particularly sensitive to the dust in the air, and fade away when it passes their limit of viability. The beautiful red Tropæolum, the summer ornament of so many cottages in the country, is one of these dust-sensitive plants. Another fact of obvious biological interest is the purifying effect of the rain. Aitken and his followers have shown, for instance, how a heavy shower may clean for a brief period the dust-laden atmosphere of a town. A gale blowing from a pure quarter has the same clarifying result.

It is characteristic of modern science that it appreciates the cumulative importance of infinitesimally small items. The commonplace that "many littles make a mickle" is a generalisation which expresses some of the grandest results of patient observation. So beside bacteria and earthworms, beside coral polyps and chalk-forming animalcules, we must rank dust as an agency of high importance. Whether it be borne on the wings of the wind from one land-surface

to another, or have what is vaguely called a "cosmic origin"; whether it be the up-blown powdery ashes of distant volcanoes, or merely the dismal "smoke-nuisance" of the world's workshop, dust is not wholly vile. For dust is the heart of the beneficent rain, and in its gentle dropping it has helped the earthworm to form the soil; it has no small share in making the sky blue above us; and it adds glory to the setting sun. Even if the east wind gloom, so familiar in Britain, be due, as Lord Kelvin said, to "the smoke of Europe moistened by the North Sea," against this we must place the fact that without dust to form the framework of the clouds, we should have no scenery in our heavens.

THE EPHEMERIDES

ONE of the sights of the year, worth a long walk to see, is the dance of the Mayflies or Ephemerides. Visit in late May or in early June some likely stream slowly flowing through the meadow, such a one as Longfellow wrote of excellently—

> "And silver white the river gleams,
> As if Diana in her dreams
> Had dropped her silver bow
> Upon the meadows low."

It is best to go in the evening—to see the living cloud rising from the water. Let us indulge in the dreamer's power of synchronous vision, and see the whole life—the long larval period of two or three years in the water, and the short aerial love-dance lasting for an evening or two. Long life indeed, but short love; years of patience and but a day of pleasure; prolonged preparations, a climax, and then the anti-climax of death. Biologically regarded, the story of the Mayflies is simply one of the many variations on the general theme of the antithesis between nutrition and reproduction.

We see the eggs developing in the water—that was three years ago—faintly stirred by the growing life within. We think of them fancifully, lapped round about by the peaceful stream; but the facts do not tally with the fancy, for the trout thin them sorely. The surviving embryos become more aware of things—that much we may surely say. Awakening from their rocking, they turn themselves in

their cradles. Then the larvæ creep forth, wash themselves in the water, and hungrily fall upon their prey of still smaller fry. The beautiful tracheal gills—we feel inclined to call them *water-wings*—are spread out, and the air in the water soaks into the blood with obviously invigorating results. The larvæ feed and grow and moult—a clearly logical sequence; they cast their cuticles time after time; they hide from the fishes.

At length there is the making of the wings and the eventful emergence from the water. They cannot fly much at first, for they are encumbered by a thin veil, too truly suggestive of a shroud. They rest rather wearily on the branches of the willows and on our clothes as we stand watching them. We see them writhe and jerk, till at length their last encumbrance, their "ghost" as some entomologists have called it, is thrown off. Then the short aerial life begins; they swing to and fro as if in a dance; they dimple the smooth surface of the water with a touch into smiling; we see them chasing, embracing, separating. There is great beauty in their film-like wings, in their large lustrous eyes (of the males in particular), in the graceful sweep of the long tail filaments.

They never pause to eat, they could not if they would. Hunger is past, love is just begun, and in the near future is death. The evening shadows grow longer—the shadow of death is over the Ephemerides. The trout jump at them, a few raindrops thin the throng, the stream bears others away. The mothers lay their eggs in the water, and after doing so many seem utterly spent, and die forthwith. Here, as often elsewhere, reproduction is the beginning of death, as well as of life. Cradle and tomb are side by side. The males also pass, almost in a sigh, from the climax of loving to the crisis of dying. Sometimes, as the old entomologists said, not a single Ephemerid is left

"to sport in the beams of the morning sun." The eggs, however, are in the water, and the race continues.

Turning homewards, the birds now silent, we cannot help thinking of other Ephemerides—of patient larval life, of metamorphosis, of shrouds angrily thrown aside and wedding robes put on, of hunger that gives place to love, of the sacrifice of maternity, of cradle and tomb together. Yet we remember the promise of the future beneath the surface of the unmoved river. The race continues. Under the horse-chestnut tree we tread upon the petals which the wind has blown like white foam, but the tree stands firm like that of Ygdrasil.[1]

[1] In the above study, as also in those dealing with earthworms and withering leaves, I have utilised some passages which I wrote and published some years ago. I have to thank Mr. Murray for his kind permission. The foundation of "The Ephemerides" will be found in my *Study of Animal Life*, p. 106 (Murray: London, 1892).

BOOK III.—AUTUMN

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IMPRESSIONIST SKETCH

THE life of plants and animals—and of man himself—is rhythmic. Rest and repair alternate with work and waste; periods of hunger and self-increase are followed by periods of love and species-continuing. There are well-established internal rhythms, and these bear a relation, partly of origin, and partly of present stimulus, to the external periodicities of day and night, month and tide, summer and winter. Just as the fatigue of evening and the sleep of night express an external punctuation of an internal rhythm, so it is with the decadence of Autumn and the rest of Winter. The external changes—more oblique light, a shorter day, increasing cold, and rising storms—act upon living creatures which have, in the course of ages, become predisposed to respond.

There is aptness in the usage which speaks of Autumn as "the fall," for life then begins to go on the down-grade. It is the ebb-tide of the year—a time of decadence. And it is largely a matter of a diminished supply of solar energy; for just as it is the sun that quickens the seeds, raises the sap, unpacks the buds, and opens the flowers, and our hearts as well, in Spring, so it is the lack of sun that now casts a spell upon life, putting the fires out and making us melancholy in the Autumn. It is the year's curfew and its vespers. When the bells cease we know the silence for Winter.

I

Even the careless, who pause only for a moment to listen to the curfew of the year, must perceive the sadness of the notes, "Farewell and Death." They are heard in the calls of the birds passing south who "wail their way from cloud to cloud," in the rustle of the falling leaves, and in the piping of a mournful wind which bears both birds and leaves away. It is truly a time of withering and decadence, of leave-taking and death.

But a more careful listener will hear very different notes, which tell of the continuance of life in spite of death, of preparation for the future amid the withering of the present. The farewell that seemed for ever is for many more accurately, "Au Revoir," "Auf Wiedersehen." For the tide of life which has now turned in ebb is not one that sinks sullen and empty from a rocky shore; it is rather like that which bears from some great seaport a fleet of richly laden ships. The ebb of the year is the time when fruits ripen, when seeds are scattered and sown; it is not an end, it is a new beginning. There is indeed stranding and wreckage, as the dead birds among the jetsam tell us plainly; but the Autumn fruits are more characteristic. They crown the plant's work for the year, and form the cradles of next year's seedlings; they protect the young lives within the seeds, and also secure their dispersal. Many of them harden, crack, and split like withered leaves, which is just what many of them are; others swell and soften into succulence. The nectaries, through which surplus sugars overflowed during flowering, forming feasts of honey for the bees and other welcome visitors, have now closed, and the sweetness is drafted into the ripening fruit. Even the fragrance of the flower may be redistilled in the flavour of the fruit, and the cheerful red glow of

the ripening apples is due to the same pigment as that in the withering leaves of the Virginian creeper, or in the gorgeous petals of the viper's bugloss, which is still erect like a standard, amid the dead and dying on the moor.

The drops of water rise to the apex of the sunlit fountain, enter for a brief moment into the formation of a rainbow, and are hurried to the earth again. Such is life. The organism rises to the crest of the wave, reaches its limit of growth, and reproduces; then is hurried from the climax of loving to the last crisis of dying. So all around us in Autumn we see the little child Love, as in the world-famous picture, holding the door against stalwart Death who intrudes. The curfew tolls, the fires of life burn low, the lights of love die out, the petals of the last poppy are shed, the butterflies disappear with the sunbeams which danced with the glistening leaves, Proserpina has perforce to go down to Hades,—many a man and beast with her,—and lowering storm-clouds draw a shroud over the earth. The music of L'Allegro has died away; hushed are Pan's merry pipes; there is no lilt of any bird; Il Penseroso begins to prose: "Dun sky above, brown wastes around you are; from yon horizon dim stalks spectral death."

In Summer, in the abundance of life we saw death harvesting; in Autumn, in the midst of death, we are impressed with the abundance of life. For Autumn is the time of seed-scattering. The cotton-grass has unfurled its white sails on the moor; clouds of thistledown and ragwort nutlets with equally dainty parachutes are swept over the waste; the hooked fruits of burdock, cleavers, hound's tongue, and how many more, cling to our clothes and to the sheep's fleece; all sorts of pods and capsules have opened, and gusts of wind—how much more the equinoctial gales—have scattered and in many cases sown the seeds. The prodigality is as unmeasurable as it is

providential. These creatures have constitutions which reproduce prolifically — prodigiously prolifically, while their forbears and cousins which were more economically reproductive have all passed away. The survivors survive, but never fortuitously. In this set of cases which we are considering, only those survived which had the sufficiently prolific constitution. They survive, not only because their constitution is strong,—that always counts for much,—but because they are many; and they are many, primarily, because it is of the nature of simple unsophisticated life to be abundant, to be prolific. It is a stream which is always overflowing its banks. And so, on this fine Autumn day, the harvest carts pass heavily laden with sheaves, strong coveys of partridges darken the stubble, the links are crowded with rabbits, the air is full of whirling seeds, the fallow-ground is vibrating with the gossamer threads of small spiders that have sunk to earth and gone into hiding, the apples fall in showers in the orchard, and we wonder, as men have wondered for thousands of years, at the Abundance of Life.

II

It would be idle to deny that there is in Autumn—the fall of the year—an irrepressible note of decadence; it is echoed in a whisper by the rustle of falling leaves. Beneficent in their life, for all the plant's wealth is due to them, they are beautiful in their dying. They have worked themselves out, for it is more than a metaphor to speak of the industry of the leaf; liquid supplies are running short, the sun's rays are fewer, the first shock of frost has come, and the leaves must die. But before they die they surrender to the plant all that they have still left that is worth having. There is a retreat of particles down the

leaf-stalk into the stem. Thus the leaves fall virtually dead, almost empty except of waste. They are like empty houses from which the tenants have flitted, breaking and burning some of the furnishings as they went, leaving little more than ashes on the hearth. But Nature is ever generous of beauty, and the dying leaves have a literal "beauty for ashes." Theirs is a euthanasia, and if we are at first inclined with the poets to weep with the withering, listening mournfully to "the ground-whirl of the perished leaves of hope, the wind of Death's imperishable wing," we must learn a deeper plant-lore,—that the leaves which by their living have made the plant rich, make it no poorer when they die; that their flush of death is a prophecy of the petal's glory—for what is a petal but a transfigured leaf? and that even when fallen they may serve as cradle-clothes for next year's seedlings. The fact remains that just as the progressive life of the species demands the death of individuals, and is within limits unmoved thereby, so the forest-tree lives strongly on though the leaves fall from its thousand branches. There are those who cannot look upon the tree in its Autumn glory without seeing the bare skeleton behind; but they must learn to look longer, and then they will see that the branches are already covered with next year's buds.

III

We hear another note of Autumn when we listen to the calls of the migratory birds, as they pass overhead by night, or congregate with excited clamouring before starting on their southward journey. It is the note of autumnal restlessness. Many little spiders show this, and pass from field to field on silken parachutes, which the Germans sometimes call "Der fliegende Sommer." There are also

strange autumnal flights of certain beetles and moths, the deer leave the heights for the low ground, and the Greenland seal comes as far south as Scotland. Man himself feels it, for many pilgrims at this season journey southward " to warmer lands and coasts that keep the sun." Some, we think, feel it strongly, perhaps in deep organic reminiscence of ancestors who were wont in Autumn to drive their herds to Winter quarters, or launched their boats and made for the northern fiords to reap their Winter harvest from the teeming waters. At this season we have known one to walk miles, day after day, simply to see the ships sailing out of the harbour, and he could give no reason for the restlessness which urged him. We can well believe that a habit begun, not coercively from without, but as the expression of a constitutional responsiveness to seasonal changes, might find organic registration.

Most sensitive of all creatures to the breath of approaching Winter—which they never face—and to hints of scarcity, are the birds whose presence made the Summer glad. Many are already gone, for the tide turned in Midsummer; " the last spent pulses of the great vernal wave of migration have scarcely ceased to flow, before the first ripples of the Autumn tide begin to be apparent." Many have slipped away, singly or in pairs, without a good-bye; others are still making up their minds, making many " last appearances," telling us excitedly day after day, " We are going, we are going."

That they should go we do not wonder, for the leaves are fallen from around their old shelters, the fruits have been gathered or scattered, the seeds are sown, most insects are dead or in safe resting-places, the daylight is short for picking up the scraps of life that remain within reach, it is becoming colder every week. We draw our

cloak about us shiveringly, as we wish the last migrants "Bon voyage!"

The history of this remarkable habit is wrapped up with the evolution of climates; thus many see in the autumnal retreat a reminiscence of the Ages of Horror which made whole faunas shudder—the Glacial Epochs. The impulse to migrate perhaps expressed originally what we have called a constitutional responsiveness to seasonal change; it seems now to be inborn or instinctive, though it may still require the stimulus of the outer world to pull the trigger. Moreover, after we have allowed all we dare allow to the experience of successive years, to the education of juniors by seniors, to a kind of social tradition in the case of those that migrate in great squadrons, we have still to fall back on the theory that a sense of direction, developed in many animals, not yet wholly lost in Man, has been brought to perfection in birds.

Of all pilgrimages—and there are many animals who travel, such as reindeer and lemmings, whales and seals, salmon and herring—this of birds is certainly the most marvellous. Picture the rush of the feathered tide, spreading sometimes for many square miles in the heavens, continuing day after day without interruption

> "Who can recount what transmigrations there
> Are annual made? What nations come and go?
> And how the living clouds on clouds arise?
> Infinite wings! till all the plume-dark air,
> And rude resounding shore, are one wild cry."

Think of the velocity of the flight, an exaltation of the bird's usual powers, perhaps reaching a hundred miles an hour. Consider the extent of the flight, the dotterel passing from the North African steppes to the Arctic tundra, the Virginian plover passing from Labrador to North Brazil. Notice the breadth of the flying phalanx;

thus that of gold-crests has been known to strike our coasts simultaneously from the Channel Islands to the Shetlands. The altitude is also noteworthy, for many birds migrate at a great height. Contrast the "wild mad rush" of Spring, when the birds fly on the whole northwards, north-eastwards, and north-westwards, at their utmost speed, by the shortest route, and almost without a break, as if love called them clamantly, with the less urgent westerly and southerly flight in Autumn, when the young birds, reversing the Spring order, are the first to leave. Nor forbid the shadow which falls over the picture, but remember of the birds as they fly that theirs is by no means always "a pleasant path in the wake of retreating Summer or in the van of advancing Spring," for migration is the great effort of their life, and to many it is the last. For the elimination which must have been raising the standard of racial fitness through the ages, since migration began, by weeding out the inept and the feckless, the dull of sense and the foolhardy, is still a dread reality. But must we not confess that the swallow flying south is "too wonderful for us"?

IV

Some one has defined life—with autumnal melancholy—as a slow dying. For, apart from the quasi-immortal Protists, whose simplicity makes its possible for them to make good their waste by constant and perfect repair, organisms always tend more or less rapidly to get into physiological arrears. Autumn is the time for balancing accounts, and then Death often claims what Love has placed in pawn. Thus, of the wasps whose nuptial flight we observed one of those harvest days, the drone-lovers are already dead, their mates have found sheltered nooks for their maternal and hibernal slumbers, and the residue, almost automatic Spartans, have

urned out all the remaining grubs from their cradles, and are themselves awaiting death in the first night's frost.

Life has also been defined as a struggle to avoid death, or as an effort towards continuance, and here again there is truth. For apart from parasites, who live the drifting life of ease, continuance means effort and struggle between the poles of love and hunger. And we undoubtedly miss part of the Biology of Autumn if we do not recognise it as a time of preparation for continued life.

The plant has been storing all Summer, and now the reserves are all passing from the more perishable parts, from leaf to stem, from stem to root. There are stores in many buds, well protected by scales which, themselves dying away, save the delicate life within ; there are stores in seeds, similarly protected by dead husks ; and so it is with tuber and root-stock, corm and bulb, all are stores.

The beavers store branches cut into convenient lengths, the squirrels store nuts, the field-mice grain, the moles earthworms, and so on through a long list. Many insects store provender for offspring which they will not survive to see. Some ants store grain, biting at the embryo and thus preventing germination ; others chew grain and store it in biscuit form ; a few take their cows—the Aphides—with them into Winter quarters. It is said that hive-bees become lazy in countries where there is practically no Winter, which corroborates the suggestion that the success of North Temperate peoples is partly due to that discipline in foresight, as well as to the emphatic punctuation of life, which the marked seasonal changes impose.

Autumn is the evening of the year, the beginning of rest, the curfew, as we said ; and we must correct the oppressive vision of a dying world with a thought of the reparation which is given in sleep. The trees, some of them already bare, the inert buds formed some months ago on the boughs,

the seeds buried in the ground, the chrysalids hidden in quiet resting-places, the eggs and larvæ under still waters, the lethargic frogs in the mud of the pond, the reptiles and mammals who have found their winter nests—they are not dead but sleeping. They await the good-morning of another spring, and though to some this never comes, of most it may be said that if they sleep, they shall do well.

V

"As is the world on the banks, so is the mind of man,"—it has its seasons too; and no one at all sensitive can avoid a suggestion of sadness in Autumn. For some, indeed, this is apt to sink into pessimism. Of this as a philosophical system, the biologist has, of course, nothing to say, but he maintains that those who find only pessimism in Autumn have been but partial students of the season, and he fancies that this may be true of even larger things. He would rest on the fact that the tree stands while the leaves fall, that there is fruition in the midst of decadence, and continuance of life in the midst of death. He knows that the apparent "Vergehen" is the condition and the beginning of a new "Werden." Even in dying he may have the joy of seeing as much as he wants of himself living on in his children. His vision of the past shows a cumulative progress of things, and gives him a sustaining hope for the future; and his evolutionary postulate that there is nothing in the end which was not also in the beginning, expresses his speechless faith that in the beginning was the Logos.

We have spoken of Autumn as the curfew of the year partly because of the covering-up of many vital fires that is then enforced, and partly also because of a memory of curfew bells we used to hear in a country village long ago, which seemed always to sadden and gladden in alternate notes—

saying, "Night and Morning, Death and Life; Night and Morning, Withering and Sowing; Night and Morning, Weariness and Rest; Night and Morning." This was a fancy, perhaps, as regards the bells, but it is a fact as regards Autumn.

Climb the hill above the village, and watch the sun set over the withering woods. Look out over the sea of gold, mingled with fire, and broken by dark rocks which you know to be pines. Accept the withering, but see also the harvest-fields; even on the bare boughs there are buds. Hear the birds pass overhead, quite a babel of good-byes sometimes, but many at least will return. Watch the seeds drift off the dead plants as the wind sighs along the hillside, and know that the race continues. Look Death in the face, and try to see that he is, on the whole, kindly and wise.

Wait till the colours pale in the short twilight, till the cows are driven home lowing, till the sheep are herded off the exposed moorland lest snow come in the darkness, till the birds that remain cease to call, till the lamps are lit in the cottage windows. Wait on till the curfew tolls, till the lights are put out one by one,—then know the rest and silence of Autumn.

"Ueber allen Gipfeln
Ist Ruh
In allen Wipfeln
Spürest du
Kaum einen Hauch;
Die Vögelein schweigen im Walde,
Warte nur, balde
Ruhest du auch."

THE FALL OF THE LEAF

LATE Autumn, which marks to many of us the beginning of Winter work and Winter pleasures, means to the wide world of life an ebb-tide—sometimes, indeed, a period for rest and recuperation, or, as is often the case, a time for dying, but always an ebb-tide. And one of the impressive and extraordinarily beautiful signs of this, more striking than the homing of the birds or the hibernation of mammals, is the fall of the leaf—the index to the fall of the year. So it is worth thinking awhile over the familiar sight of the withering and falling leaves.

We have seen that the life of the plant is tidal ; it sets in with a flood in Spring, manifesting itself in growth of stem and exuberance of foliage ; it rises to the high-water mark, and turns in Summer when the blossoms burst and the flowers shine forth ; it is well on the ebb by Autumn, bearing on its breast all manner of ripe fruits and seeds, potent treasures to be cast on the shores of another Spring. Each of these tidal periods, one may say, has its characteristic colour : green and gold are the colours of young Spring ; orange, red, and purple mark the full splendour of Summer flowers ; and Autumn, with its flame-like, often blood-like, withering leaves, rivals all that has gone before. Is it not true to say that the ebb-tide gleams with the glare of burning wrecks ?

Throughout the Summer the leaf has lived an intense life, far more intense than we are inclined to give plants credit for, building up with the aid of the sunlight no small

quantity of sugar and more complex carbon-compounds, which are laid up in reserve in various parts of the plant. In Autumn, however, the vitality is checked; the movements of the sap become very slight; and the leaves begin to die. It is partly that they are in some measure worn out by the Summer's work, just as the bees are; it is partly that the physical world has changed. It is well that they should die, lest they begin to undo what they have so well done.

But before they die they behave in a beautifully adaptive way. They surrender to the plant that bears them all the residue of their industry that is worth having. There is a gentle current of sugar and more complex things, even, they say, of the subtler wealth of living matter, which ebbs from the dying leaf into the stem before the breath of approaching Winter.

The leaf, useful in dying as well as in living, becomes more and more empty of all but waste, and as the retreat of valuable material into Winter quarters is being accomplished, there is also preparation for the actual fall. Across the base of the leaf-stalk, in a region which is normally firm and tough, there grows inward a partition of soft juicy cells, actively multiplying and expanding into a springy cushion, which either foists the leaf off, or makes the attachment so delicate that a gust of wind will soon snap the bridge binding the living and the dead. This is fine surgery, that the scar should be ready before the operation is performed. The more we look into the matter the more we see how perfect are the adaptations connected with the fall of the leaf.

Virtually dead the leaves now are, empty houses, all dismantled, with little more than ashes on the hearth. But these ashes—how glorious! for in yellow and orange, in red and purple, in crimson and scarlet, the withering leaves

shine forth. They are transfigured in the very article of death, in the low beams of the Autumn sun.

One of the most interesting interpretations of the yellow colour of many leaves in Autumn (and also of the pale yellow—etiolation—of newly unfolded leaves in Spring) is in terms of economy of material. Pure green chlorophyll contains carbon, hydrogen, oxygen, nitrogen, and magnesium; the yellow colouring-matters contain only carbon, hydrogen, and oxygen. Thus, "by keeping back the green chlorophyll in the Spring and reabsorbing it in the Autumn, a saving would be effected in nitrogen and magnesium, which are of great value to the plant."

Professor Stahl in particular has worked with this interesting theory, for which there is considerable evidence. When a leaf just about to turn yellow is taken from the plant and kept in a moist chamber it remains green, while its neighbour on the plant has changed to yellow. There seems to be a migration of the green chlorophyll. When the veins connecting a corner of leaf with the midrib are severed, the corner remains green, while the other parts remaining in connection with the main conducting vessels change to yellow. Chemical analysis has shown that in the yellow leaf, as compared with the green leaf, there is a reduction in the amount of potassium, nitrogen, phosphoric acid, iron, chlorine, and silica.

Sometimes it is the double green pigment—the chlorophyll—of the leaf that breaks up, forming little heaps of yellow grains, and the leaves are golden. Sometimes, on the other hand, amid the flux of molecules in the dying leaf, there appears a special decomposition product—anthocyanin, which along with the acids so often present stains the leaf with red, or without the acids gives us bluish purple, or along with the yellow grains above mentioned shines out in gorgeous orange. It goes without

SQUIRREL AND FALLEN LEAVES IN WOOD

(IX)

saying that the details of the process are intricate, and that they vary considerably from plant to plant.

Finally the leaves fall gently from the trees, or after writhing and rustling in the wind, as if loath to be separated, are violently wrenched off and whirled along the ground. Who can help hearing in this ground-whirl of perished leaves "the wind of Death's imperishable wing"? But although we cannot ignore the curfew of the year, tolling insistently in October, we recognise that the tree is not really impoverished by the yearly loss of its leaves, while they, on the other hand, weathered, faded and torn, and mouldered by fungi, are buried by earthworms, to form, with the help of bacteria, the vegetable mould in which are born the seedlings of another year.

When we look back on the full Summer tide, Autumn seems indeed to be bare and sad, especially in northern countries. The fields are stripped; the hedgerows are silent; withered grass, blackened herbage, and leafless boughs contrast almost painfully with Summer's pageant. But it is well to make the most of the present—to go before it is too late to some height among the woods and watch the waves of colour splashing in the wind. Let us gather some browned bracken, lighten it up with leaves of oak and rowan tree, brighten it with a branch of a bramble, throw in Virginian creeper and vine if we have them, and let us recognise with gladness the persistent glory of the year.

Let us look forward, too, and see how the withering leaves often prophesy the splendour of future flowers, and recognise that the leafless boughs are only resting, husbanding their strength for the triumphal outburst of Spring. The buds are already there, the vigour of the leaves that have fallen has given them their initiative.

The leaves live and die for the plant, which is enriched by their Summer's work, and saved by their Autumn fall.

And in their death, which seems to us very beautiful, we see an expression of fundamental facts which have their application to ourselves, that the life of the species requires the death of individuals, that sacrifice is essential to progress, and that while the leaves fall from its many branches the tree of Life lives strongly on.

SHOWERS OF GOSSAMER

WE read of the Indian conjuror who throws a rope into the air and climbs up it, but we can see spiders actually doing something of this sort. It is especially, though not by any means exclusively, in the Autumn that threads of silk may be seen floating in the air, just visible when the sunlight makes them glisten, or entangled in incredible numbers on hedgerows and among the herbage. Sometimes as we walk over the links and stoop down to look along the short grass, we see that it is quivering with myriads of silken lines,—the fallen threads of gossamer, often iridescent in the sunlight.

The Germans sometimes call it "Der fliegende Sommer," and the French "Fil de la Vierge," and there is possibly in the name gossamer an even more poetical suggestion. But it is fine enough in itself to dispense with uncertain etymological decorations. Of the fleeting Summer it is indeed a hint, but it seems to occur in Britain at almost every season, when there is fine clear weather.

Gossamer showers have attracted attention from early times; thus Pliny records how it rained wool about the Castle Carissa, and now and again they occur on such a large scale that they force themselves on the attention of the most careless. A good example is recorded in Gilbert White's 23rd Letter :—

"On the 21st September 1741, being then on a visit, and intent on field diversions, I rose before daybreak: when I came into the enclosures, I found the stubbles and

clover-grounds matted all over with a thick coat of cobweb, in the meshes of which a copious and heavy dew hung so plentifully that the whole face of the country seemed, as it were, covered with two or three setting-nets drawn one over another." The dogs could not hunt, "their eyes were so blinded and hoodwinked that they could not proceed."

"About nine an appearance very unusual began to demand our attention, a shower of cobwebs falling from very elevated regions; and continuing without any interruption till the close of the day." These webs were not single filmy threads, however, but "perfect flakes or rags." "On every side as the observer turned his eyes might he behold a continual succession of fresh flakes falling into his sight, and twinkling like stars as they turned their sides towards the sun."

In most cases the natural history of gossamer is as follows: Young spiders and small spiders of a good many different kinds seem to become restless in the Autumn. They mount on the tops of plants, on fences, on the hand-rail of a wooden bridge and the like; they stand on tiptoe with their head facing the gentle currents in the air; they emit from their spinnerets fine separate threads of silk. They stand on tiptoe, but keep firm hold until the threads of silk floated out on the breeze (if one may say so) are sufficient to bear them. Then with a vault they let go, and are borne by the gentle currents often to great distances.

They have, of course, no power of directing their movements, but it seems likely that they can add to their parachutes (setting more sail) or coil it up in part (taking in a reef), so that they float farther or sink gently to the earth, as the case may be. When tens of thousands of small spiders do this on some suitable Autumn day, we see a flight or shower of gossamer. Some of the spiders —many different kinds indulge in ballooning—are borne

far—often, doubtless, too far. Thus Darwin noted that huge numbers were carried on board the *Beagle* when it was sixty miles off shore. There are other spiders, however, which cannot make long journeys, and do not rise high off the ground. Professor Miall has observed that gossamer in the air is always preceded, as well as followed, by gossamer on the ground. A further study of gossamer-making British spiders is much to be desired.

In his fine work on *Spiders* (1890), Dr. M'Cook notes the interesting fact that the essential explanation of gossamer was discovered in 1716 by a boy of twelve, Jonathan Edwards, who afterwards became famous in other connections—as an author, for instance, of a treatise on *The Freedom of the Will.* He saw and figured the "flying spiders," and seems to have clearly understood that the aeronaut was supported by the silk, and that it was borne by currents. "If there be not web more than enough just to counterbalance the gravity of the spider, the spider, together with the web, will hang in equilibrio, neither ascending nor descending otherwise than as the air moves; but if there is so much web that its greater rarity shall more than equal the greater density, they will ascend till the air is so thin that the spider and web together are just of an equal weight with so much air." Which is not amiss for a boy of twelve. Nor is his note on the silk itself: "Seeing that the web, while it is in the spider, is a certain cloudy liquor with which that great bottle tail of theirs is filled, which immediately, upon its being exposed to the air, turns to a dry substance, and exceedingly rarifies and extends itself."

Some details of one of the most remarkable phenomena in Nature have been furnished by trustworthy observers and experimenters, who have followed up the excellent beginning made by the boy Jonathan Edwards. Gilbert

White wrote in 1775: "The remark that I shall make on these cobweb-like appearances, called gossamer, is that, strange and superstitious as the notions about them were formerly, nobody in those days doubts but that they are the real production of small spiders, which swarm in the fields in fine weather in Autumn, and have a power of shooting out webs from their tails, so as to render themselves buoyant and lighter than air."

Inquiring into the problem why what rises should again sink, he says: "If I might be allowed to hazard a supposition, I should imagine that those filmy threads, when first shot, might be entangled in the rising dew, and so drawn up, spiders and all, by a brisk evaporation into the regions where clouds are formed; and if the spiders have a power of coiling and thickening their webs in the air, as Dr. Lister says they have, then, when they were become heavier than the air, they must fall."

Very interesting, in its mixture of keen observation with a slight laxity of analysis, is the concluding paragraph of the twenty-third letter. One quotes it, quite naturally, as if it were a sacred book. It is certainly one of the Pentateuch of "Nature-Study."

"Every day in fine weather, in Autumn chiefly, do I see those spiders shooting out their webs and mounting aloft: they will go off from your finger if you will take them into your hand. Last Summer one alighted on my book as I was reading in the parlour; and, running to the top of the page, and shooting out a web, took its departure from thence. But what I most wondered at was, that it went off with considerable velocity in a place where no air was stirring; and I am sure that I did not assist it with my breath: so that these little crawlers seem to have, while mounting, some locomotive power without the use of wings, and to move in the air faster than the air itself."

Dr. H. C. M'Cook, who has contributed so much in a charming way to our knowledge of North American spiders, gives a precise account of the spider's position during the ballooning; and it is interesting to notice, as he points out, that here again the gist of the matter was accurately observed by Master Jonathan Edwards. "As the spiderling vaults upward, by a swift motion the body is turned back downward, the ray of floating threads is separated from the spinnerets and grasped by the feet, which also by deft and rapid movements weave a tiny cradle or net of delicate lines, to which the claws cling. At the same time a second silken filament is ejected and floats out behind, leaving the body of the little voyager balanced on its meshy basket between that and the first filament, which now streams up from the front. Thus our aeronaut's balloon is complete, and she sits or hangs in the middle of it, drifting whether the wind may carry her."

Dr. M'Cook makes a useful suggestion in regard to the shreds and flakes often seen floating or sinking down without any spiders about them. "In many, perhaps in most, cases a number of feints are made before ascent. A spider will take due position and spin out a thread; but it fails to mount aloft. Other unsuccessful attempts follow, each producing a filament. These, while waving to and fro in the eddying air, are often tangled together before they are whipped off. Others again are united in the air after release."

As we have seen, the Natural History of gossamer has been in great measure cleared up. There is still much to do in the way of filling in details, but in a general way we can describe how gossamer is made and how it comes to be as it is. It must be frankly confessed, however, that we do not understand the biological significance of what we are able to describe. It may be that these young spiders are dispersing,

as young creatures tend to do, from the parental home, where there is no longer room for them. It may be that the pinch of hunger is making itself felt. It may be, on the other hand, that there is an element of play and even adventure in the business. We use the word "adventure" advisedly, for spiders are alert, intelligent, original, individualistic creatures, very different from ants and bees, and other oversocialised creatures of instinctive routine. Once more, it is possible that the ballooning may be, to some extent, like letting off steam; it may be that certain conditions induce an overproduction of silk; this has to be got rid of, and some spiders get rid of it in a highly original way. But we are not trying to obscure our admission that we do not know the biological significance of gossamer.

In any case, the extraordinary beauty of gossamer remains a fact. Every alert person who has seen a long stretch of golf-course, or acres of ploughed land, or a piece of moor, or half a mile of hedgerow covered with gossamer, must have admired the sight. The admiration grows when the gossamer is bediamonded with dew or silvered with the frost, or when the sun makes rainbows among it. It is one of the most beautiful things in the world; and when the threads along the ground sparkle and vibrate, the earth seems to be quivering, like a living thing, as far as the eye can reach. It seems like an emblem of the intricacy of the threads in the web of life. It recalls insistently Goethe's famous words about Nature—"She moves and works above and beneath, working and weaving, an endless motion, birth and death, an infinite ocean, a changeful web, a glowing life."

THE SIGNIFICANCE OF PALOLO

ONE of the most striking illustrations of the rhythmic swing of life is to be found in the story of the "Palolo" worms, which, briefly told, is somewhat as follows. Among the crevices of the coral rocks around Samoa and Fiji and some other Pacific islands, there is a very common greenish sea-worm, scientifically named *Eunice viridis*, popularly Palolo. In October and November every year, on or near the day of the last quarter of the moon, there is an extraordinary breeding swarm, and the waters are green with worms. The swarming sets in just before sunrise, and often lasts for less than half an hour. The numbers are past all conception. The water is so thick with worms, Professor Hickson says, that one cannot see down below two or three inches. Professor Alexander Agassiz compared the sight to a great area of thick vermicelli soup. It is a red-letter day for the natives, who collect the delicate creatures in vessels and have a great feast, as their forbears seem to have done for many generations. It is said to be a red-letter day for the land-crabs also, who arrange at that time to visit the worm-strewn beach. What does it all mean?

To understand it, we may begin near home by noticing that in some of our British shore-worms, such as the resplendent *Nereis virens*, a remarkable change occurs in the body at the breeding season. So striking is the transformation in some instances, that the breeding ("epitokous") phase has been mistaken for a distinct species. In some forms the change affects only a part of the body, the posterior

part becoming dilated and embellished, so that the animal as some one has put it, is like a caterpillar in front and like a butterfly behind. In many species, especially in the family of Syllids, part of the body, laden with germ-cells, is set adrift at the breeding-season, and, after swimming about for a while, breaks up in the waters. This is what happens with the palolo.

For the strangest feature of the palolo-swarm is not in the enormous numbers—since the shore abounds in prolific animals; nor in the regularity of occurrence—since Nature is full of these subtle rhythms; nor in the fact that these burrowers among the coral should be swimming in open water, in a pelagic agony rather than a pelagic existence (as Professor M'Intosh puts it)—since many shore-animals have a pelagic or semi-pelagic phase in their life-history; but surely this, that all these writhing worms are headless. In the most literal sense, they have all lost their heads; they are not worms, but parts of worms—the detached posterior portions laden with germ-cells.

The story of the Pacific palolo is so extraordinarily diagrammatic that no apology is needed for re-emphasising its biological significance by noticing what happens with its congener at Tortugas, Florida, *Eunice fucata*, the "Atlantic palolo." Dr. Alfred G. Mayer, who has made a great stride by his studies in the intimate physiology of jelly-fishes, has given a fine sketch of the annual event.

"The habits of the 'Atlantic palolo' are quite similar to those of the palolo worm of Samoa and the Fiji Islands. The worms are, however, specifically different, the Atlantic palolo being *Eunice fucata* Ehlers, and the Pacific worm *E. viridis* Gray. Moreover, the annual breeding-swarm of the Pacific palolo comes upon or near the day of the last quarter of the moon in October and November, whereas the Atlantic palolo swarms within three days of the day of the

last quarter of the moon between 29th June and 28th July."

The Atlantic palolo worms live within the crevices of coral rock below the low-tide level. When mature they are about 10 in. long and like thick string in girth. Before sunrise on the morning of the day of the annual breeding-swarm, the worm crawls out backwards from its burrow and protrudes the sexual segments, which exhibit a screw-like twisting and break off at a particular point. "On being set free, they swim vertically upward to the surface, where the posterior end of the worm continues to progress rapidly along, moving backward."

The male "ends" are salmon red or dull pink; the female "ends" are greenish-grey or drab—the sex-contrast eking itself out in colour. If an end be cut, each piece continues to swim backward with its characteristic rolling movement. Normally each worm—if we can call it a worm—pursues its own course, "without regard to its fellows of either sex"; and they may be so abundant "that hardly a square foot of the surface above the coral reefs at Tortugas was free of a worm."

"When the sun is about to rise, and the first faint rays of light fall over the ocean, the worms begin to contract violently, so that the sexual products are cast out through rents and tears in the dermo-muscular wall, and the torn and shrivelled cuticula sinks down to die upon the bottom. Light is not the sole, but only a contributory, cause of this muscular spasm of contraction. . . . Any mechanical shock will bring about an instant bursting of the worm, the females being far more sensitive than the males."

"After casting off its posterior sexual segments, the anterior part of the worm crawls back into its burrow and regenerates a new sexual end. Only the mature worms cast off their posterior ends; the immature worms take no part

in the swarming reaction." Now we begin to realise the true inwardness of the phenomenon. At first we were inclined to see, what is so obvious at many levels both in plants and animals, that the beginning of new lives means the waning of the old. But what we have is a quaint suggestion of the little child Love holding the door *defiantly* against the entrance of stalwart Death.

For the whole point of the palolo-swarm is that it illustrates an evasion of the death-penalty on reproduction. The trend of things says, as it were, to the *Eunice*, in the origin of a new generation the parent must sacrifice itself. But the palolo has answered back, which is the prerogative of life, transcending all materialisms—has answered back effectively, by the extraordinary adaptation of parting with no small part of its body, and yet living on. In the face of the trend of things, it hurls the defiance "Non omnis moriar," and it still keeps true to its boast. And this is *Life*—an automatism that can rebel.

The Pacific palolo swarms, as has been noted, upon or near the day of the last quarter of the moon in October and November; the Atlantic palolo has its principal swarm within three days of the day of the last quarter of the 29th June to 28th July moon, but the worm sometimes responds to the first as well as to the last quarter of the moon; the Japanese palolo swarms in the Tokyo river at the time of the new and the full moon.

Dr. Mayer has tried to discover the nature of the stimulus to which the Atlantic palolo responds when it swarms. He put some rocks with worms in them in a scow-shaped live-car, which was floated, half-full of water, on the sea. Thus an artificial "tideless sea" was arranged, and the interesting result was that four out of eleven worms swarmed normally.

"In nature *all* of the mature worms swarm at the

annual breeding-time, and this partial failure of the worms to swarm may indicate that the changing pressure due to rise and fall of tide over the reefs is a contributory, but *not a necessary*, component of the stimulus which calls forth the breeding-swarm. It is more probable, however, that confinement within the wood-inclosed space of the live-car and the lack of perfect circulation of water acted as a partial preventive of the swarming, and that the reaction is wholly independent of the rise and fall of the tide. In any event, it is evident that the worms *can* swarm normally in a tideless sea, and that rise and fall of tide is not a necessary or sole cause of the swarming."

On the other hand, when the scows were provided with light-tight wooden covers, so that the moonlight was kept off, none of the worms swarmed. It seems, therefore, that the worms require the stimulus of the moonlight. "In nature the worms will swarm in overcast or cloudy weather, so that even diffuse moonlight appears to be capable of calling forth the breeding-season." We have here, therefore, a striking instance of a constitutional change that is, so to speak, punctuated by an external periodicity.

Dr. Mayer calls attention to another very interesting aspect of the phenomenon. In the Atlantic palolo the annual breeding-season is only of one to six days' duration, and the males outnumber the females in the ratio of about three to two; whereas in Nereis, where the breeding-season is fully one hundred days long, the males greatly outnumber the females. "It is evident that a shortening of the breeding-season would cause a greater concentration of breeding individuals, and would therefore permit of a relative *decrease* in the number of *males* and a corresponding *increase* in the number of *females*; for, whenever a female swarms, it is important, for the preservation of the species, that there should be a male near her to fertilise her eggs.

If the breeding-season be of long duration, the males must greatly outnumber the females to secure this fortuitous proximity; but if all of the females swarm within a few days, very much fewer males will suffice to accomplish this purpose."

"We have advanced beyond the period in the history of biology when one had but to discover an advantage to determine a cause; but that some such cause may have contributed to shorten the breeding-season in such animals as the Atlantic, Pacific, and Japanese palolo worms is shown by the fact that more eggs are fertilised when males are near the female than when they are far away."

Thus we find in the palolo a fine instance, on the one hand, of evading the penalty so often imposed on reproduction, and, on the other hand, of securing prodigal multiplication while economising reproductive expenditure.

AUTUMN FRUITS

ALTHOUGH autumnal changes are the beginning of the end to annual plants and animals, and involve a check to the vitality of many others that are longer lived, there are other processes which work in a life-preserving direction. There are preparations for the Winter, such as the laying up of stores inside the bodies of plants and animals, or outside the body as well in the case of animals; and there are preparations for next year, such as the completion of bud-making or the regrowth of damaged feathers. One autumn night we sat looking down on the village from the hill above, and as we watched all the lights were put out one after another, though sometimes it was simply that the blinds were drawn and the shutters closed; we felt that the day was indeed over; but as we looked longer, there rose in our mind the picture of banked-up fires, of things set in order for the morning, and of other preparations for a new day, besides the chief preparation of rest. It is the same in the household of Nature. When we turn to fruits, however, we have to do with preparations, not for the individual, but for the continuance of the race. In a sense they crown the plant's work for the year, but their significance is not individual. They protect and scatter the seeds, but all that is in them is loss to the individual plant. In the organic see-saw between nutrition and reproduction, fruiting is the extreme uplift of the reproductive end.

A fruit, regarded structurally, is the part of the flower

that persists after pollination has been effected—that is to say, after the possible seeds or ovules have become real seeds. In most cases a fruit may be described as the ripe seed-boxes, or as a collection of ripe seed-boxes, with or without extra parts, such as the fleshy top of the flower-stalk or a persistent calyx. In some cases, as in common cereals, where a single seed fills the seed-box, fruit and seed are practically identical, though the theoretical difference remains clear. In order to understand the different kinds of fruits, which represent different solutions of a very interesting problem, we must also notice that the wall of the fruit (the pericarp) often consists of several layers, very different from one another. Thus in the familiar case of a plum there is the firm outside skin (epicarp), which keeps bacteria and moulds out until it gets even a slight wound; there is the fleshy pulp (mesocarp), which is all loss to the parent plant, but attracts the birds, which scatter the seeds; and there is the very hard "stone" (endocarp), which effectively preserves the seed within—a living embryo—from being digested in the bird's food-canal, from being frost-bitten in the ground, from premature germination, and from other risks.

The use of the fruit is to secure a measure of success for the seeds; but this requires analysis. (1) The seed is an embryo plant with a legacy of nutritive material; it grows within the ovule from a microscopic egg-cell fertilised by a pollen-grain; it is, for a time, a very delicate young life. One use of the fruit is to protect the developing seed from bad weather. (2) Even when the seeds are fully formed and have attained to great tenacity of life, there is need for the fruit's protection, for instance, against small seed-eating animals, such as boring beetles, or against larger creatures, such as birds and rodents, which devour and

digest the seeds. (3) Not less important is the part the fruits play in seed-scattering—which we propose to discuss by itself—whether by explosion, or by adhesion to animals, or by the formation of parachutes, or otherwise—including, of course, by being themselves eaten! (4) But even when the seed has been successfully scattered and sown it may require the fruit's protection in the ground. It may not be ready to germinate, or the season for germination may be many months ahead. The enclosing fruit, or its innermost wall in many cases, may protect the seed from the frost and from the appetite of many small animals that work underground.

It is almost impossible to avoid using phrases which suggest foresight on the plant's part, or some deliberate fashioning of the fruit—which is of no use to itself—so as to secure seed-scattering and seed-protection. But, while the fact of adaptation is certain and becomes more and more impressive the more we penetrate into its details, and while it may be necessary to postulate a certain primary adaptiveness in living creatures—a capacity for effective response to stimuli and of effective creation of what is new—we cannot, of course, imagine that the plants take thought for the morrow or for the future of their race, even in the most figurative sense. We must look at the matter in a different way. Those plants that, for constitutional reasons of their own, varied in the direction of having effective fruits were the plants that survived. Those plants that, for constitutional reasons of their own, did not vary in the direction of having effective fruits were eliminated from their place in the Earth's Flora. It is a useful biological dictum that nothing succeeds like success; for when a plant, aiming at no mark (save, perhaps, its own organic equilibrium and self-increase), made a hit in the direction of an effective fruit, it would have

great success with its seeds, and its valuable idiosyncrasy would be handed on, for subtle reasons perhaps *augmented*, to an ever-increasing body of descendants.

Turning now to the many different kinds of fruits, we must, from a general biological point of view, regard the great diversity as an interesting illustration of the variety of solutions that may be offered to one vital problem. Linné recognised five different kinds of fruits, and Lindley thirty-six; but as this is not a botanical treatise, the smaller number will suffice. First, there are the *box-fruits*, or *capsules*, dry in character, and liberating the contained seeds. Poppy-heads and pea-pods at once suggest themselves as examples. Second, there are *splitters*, or *schizocarps*, also dry, but *not* liberating the seeds. They break into pieces, each of which encloses a seed. This is true of the fruits of the hemlock and all Umbellifers, of mallows, of Labiates. It is enough to look into the calyx of a ripe White Dead Nettle to see that the fruit has neatly divided into four nutlet-like pieces, each enclosing a single seed. Third, there are *nuts* and *nutlets* (achenes), also dry and not liberating the contained seed. In true nuts, such as those of the hazel, there is a very hard fruit-wall, to which the enclosed seed is not adherent; in the fruits of a buttercup (achenes) the wall is not hard, and the enclosed seed is not adherent; in grains of wheat the fruit-wall is somewhat leathery, and the envelope of the seed is adherent to it. This may serve as an illustration of how classification proceeds, division within division, as long as there is a clear basis of distinction.

Turning from the dry to the succulent fruits, we find that there are two main kinds. There are the *stone-fruits*, or *drupes*, with three layers, the middle one more or less juicy, and the innermost one (the "stone") always very hard. Cherries and plums at once suggest them-

PARTRIDGES IN HARVEST FIELD

(X)

selves as examples. Lastly, there are *berry-fruits* in the wide sense, where the seeds are embedded in pulp, as in the case of gooseberry and currant and grape.

Besides these so-called simple fruits, each of which represents one seed-box or ovary, there are more difficult compound fruits, such as a strawberry, which is a collection of tiny nutlets embedded on the surface of the fleshy apex of the flower-stalk; or a bramble-fruit, which is a cluster of drupes; or a rose-hip, which is a collection of nutlets inside the fleshy apex of the flower-stalk turned into a cup. There are others, still more compound, which correspond to a whole inflorescence or group of flowers, such as the fig, which is a collection of fruits within a juicy flower-stalk. The pine-apple is another familiar example; it seems to be a collection of fleshy berries and fleshy bracts.

It may be noticed, too, that there are some very difficult cases in regard to some of which the botanists themselves are not always agreed. The fruit of the juniper seems to be a reduced cone that has become fleshy; in the yew there seems to be a naked seed partly surrounded by a fleshy seed-mantle or aril; in the pomegranate the coats of the seeds have become juicy; the banana is, perhaps, a long seedless berry; the cucumber is a berry with a tough epicarp; the orange is a many-chambered berry with juicy partition-walls and a leathery epicarp rich in oil cavities; and even the apple is often regarded as a berry.

It is easy to make fun of "botanical conundrums": "Why is a strawberry not a berry, when a date is?" But while an understanding of fruits will not be helped by pedantry, it is likely to be helped by precision. To see things clearly is often the first condition of insight. Therefore, it is profitable to delay for a little, puzzling over the real nature of certain difficult fruits. Let us take in

illustration some of the fruits that are popularly and erroneously called "nuts." Why is a Brazil-nut not a nut? Because it is a seed—one of many from a large box. Why is a pea-nut not a nut? Because it is a pod. Why is a walnut not a nut? Because it is the stone of a drupe. Why is a horse-chestnut not a nut? Because the fruit is really a capsule with big seeds. Why is a cocoa-nut not a nut? Because it is the stone of a large drupe with a leathery epicarp and a fibrous mesocarp. The hazel has a typical nut with a sheath of succulent bracts at the base; the beech has three-sided nuts with woody external bracts; the acorn is a nut with an extra scaly cupule.

Towards an understanding of fruits, a few suggestions may be offered. In the case of succulent fruits, we have to remember that the green plant is a sugar-factory, that it is an extremely anabolic organism with an income greatly n excess of its expenditure, that it makes very much more sugar than it needs, that some of this surplus overflows in the nectaries of the flowers, and that after the nectaries close up the surplus may be drafted into the fruit. Having got this elementary but fundamental fact clear, we may go on to the secondary interpretation that juicy fruits are well adapted for seed-scattering by fruit-eating birds, and that plants with juicy fruits will therefore, in certain conditions, prevail.

Again, in regard to fruits of the capsule type, which liberate the seeds by splitting, either gently or explosively, we have to remember that the sides of the box are usually the carpels—that is to say, *leaves* modified for the production of seeds. These carpels, like other leaves, are organs of a limited length of life; they are likely to die and wither, and crack and shrivel, and fall off like other leaves. And, again, it is this primary fact that should come first, and

insistence on the survival-value of the bursting of box-fruits that should come second.

When we inquire into the chemistry of fruits one big fact stands out clearly, that they have relatively little of the more valuable reserve-stuffs. They have relatively little proteid material, but if they are succulent they may have much water and sugar. Seeds, on the other hand, are rich in proteids, and the advantageousness of this is plain, when we recognise that what is spent in the fruit is lost, while what is stored in the seeds is legacy. Apart from the seeds, it is said that it requires 1½ lb. of grapes, 2 lb. of strawberries, 2½ lb. of apples, and 4 lb. of pears to furnish as much proteid as there is in one egg.

In the ripening of the fruit many interesting chemical changes go on. There are fermentations, for instance, such as that which changes the starch of the unripe fruit into the sugar of the ripe fruit, or that which changes pectose into pectin. There is the appearance of pigments, such as the anthocyanin of the rosy-cheeked apple, which is the same as the red of the withering leaf and of some flowers. There is also the formation of ethers and oils and other subtle compounds, some of which are aromatic, giving the fruit a fragrance which is sometimes even finer than that of the flower.

SEED-SCATTERING

MAN is harvesting and gathering into barns, but Nature is scattering abroad and sowing, and nothing is more characteristically autumnal than this dispersal of seeds. It is one of the most interesting chapters in the Natural History of the Seasons.

The import of the scattering is partly, of course, just sowing, but it is also advantageous that what is sown should be carried away from the shadow of the parent plant or away from a crowded area. It is well that the family should scatter. There is an attendant disadvantage that many are lost altogether, and that others are borne into very unsuitable situations. That the advantages must in many cases far outweigh the disadvantages of dispersal, may be safely inferred from the fact that the adaptations securing it are so numerous and varied.

Perhaps the simplest of all ways is seen in box-fruits which break up and allow the seeds to tumble out. They may rebound to some distance when they fall, or they may be blown by gusts of wind, or they may be carried by runlets of water. The ants sometimes take the seeds of the cow-wheat (*Melampyrum*) into their nests, as if they mistook them for their own offspring, for they are not very unlike cocoons.

It is evident, however, that the gentle breaking up of a box-fruit can be improved upon, and there are various degrees of explosive dispersal, from the popping of whin-pods and broom-pods, which we often hear when sitting

quietly in the country, to the energetic slinging of the balsam (*Impatiens noli-me-tangere*). More extraordinary is the almost animal violence of *Hura crepitans*, which breaks into pieces, as if an explosive bomb, "with a report like that of a pistol." In all cases what happens is, that when the dying of the walls of the fruit reaches a certain stage, there is a sudden release of certain tissue-tensions, and hence the explosion. "In the case of the box (Buxus), the smooth seeds are forcibly discharged by the contraction of the pericarp, like a bean pressed between the fingers." The pulling of the trigger is often due to the state of the weather.

Another simple method of dispersal is illustrated by a few dry fruits which adhere readily to passing animals, such as rabbits, and eventually fall off, it may be far from the site of the parent plant. The little brown nutlets of Jack-run-the-hedge or cleavers (*Gallium aparine*) are covered with asperities which take a firm hold; those of the burdock have long crochet-needle-like hooks; and the awns of grasses are also very effective for adhesion. The fruits of Medicago are common in the fleece of sheep, but it is difficult to regard this as a profitable mode of dispersal.

The similarity of aquatic plants and animals in far-separated freshwater pools is often very striking, and part of the explanation is certainly, as Darwin pointed out, that water-birds transport seeds and germs from pool to pool on the mud attached to their feet. The same is true of land-birds, which get clodlets fixed on their damp feet. Darwin made a thorough study, after his wont, of the fauna and flora of birds' feet, collecting the clodlets and moistening them, to see what would come forth. He proved up to the hilt the importance of this mode of transport, and he was rewarded on one occasion by

obtaining from one bird no fewer than eighty germinating seeds.

This classic case may be quoted: "Professor Newton sent me the leg of a red-legged partridge (*Caccabis rufa*) which had been wounded, and could not fly, with a ball of hard earth adhering to it, and weighing $6\frac{1}{2}$ oz. The earth had been kept for three years, but when broken, watered, and placed under a bell glass, no less than eighty-two plants sprung from it; these consisted of twelve monocotyledons, including the common oat, and at least one kind of grass, and of seventy dicotyledons, which consisted, judging from the young leaves, of at least three distinct species. With such facts before us, can we doubt that the many birds which are annually blown by gales across great spaces of ocean, and which annually migrate—for instance, the millions of quails across the Mediterranean—must occasionally transport a few seeds embedded in dirt, adhering to their feet or beaks?"

A third method of dispersal is by means of parachutes, which make it easier for the fruits to be carried by the wind. We see the thistle-down and dandelion-down with their beautiful hairy parachutes "sailing before the wind." It is interesting to watch one enter by the open window of a railway carriage, sail around once or twice, touching the cushions for a moment, and then move on again, finally passing out where it came in. There is something curiously animal-like in its visit of inspection. An unforgettable sight is a flight of clematis fruits—each a nutlet tipped with a long white feathery plume. It is the hoary appearance of the ripe fruits, massed together on the hedge, that gives the plant one of its common names, Old-Man's-Beard. When the fruits are set free by the breeze, the plumes are often entangled in long rows, which float off with a beautiful undulating motion, like silver serpents in

the air. Strasburger refers to an experiment with the hairy fruit of the artichoke, which was allowed to sink in vacuo and in the air. "Compared with the accelerated fall in a vacuum, the retardation exerted by the resistance of the air (by which the opportunity for dispersal through the agency of the wind is enhanced) is, in the first second, as six to one."

Another form of the parachute adaptation is seen in the winged fruits of the maple and the ash and the elm, and some other trees. In the case of the maple there is a heavy nutlet at one end; the other is prolonged like an insect's wing. If we throw the fruit into the air, as every country schoolboy knows well, it sinks slowly down with a beautiful twisting motion at some distance from where we are standing. So, when this fruit is torn from the tree by the wind, the parachute not only acts in a general way like a float, giving the wind time to get a grip of it and whirl it away, but it causes that peculiar gyrating fall that even on a quiet day carries it far beyond the tree's shadow. The importance of this for the seedling is obvious.

Any structural peculiarity that increases area without increasing weight will aid in wind-dispersal, and it is interesting to notice that the same result is reached in many different ways. The wings may be expansions of the sepals, or of the seed-box, or of the seeds themselves. "In a Bignonia seed, with its widely outspread glossy wings, the centre of gravity is so disposed that the seed floats lightly along through the air in an almost horizontal course, and with a motion like that of a butterfly" (Strasburger's *Botany*, p. 291).

In some cases the currents that transport seeds and fruits are in water, not in air, and there may be structural peculiarities that suit this well, such as water-tight tissues

and gas-floats. In no other way could coco-nuts be carried to isolated and uninhabited coral-islands, where they sometimes form the beginning of terrestrial vegetation. Writing of Keeling or Cocos Islands, coral formations in the Indian Ocean, about six hundred miles distant from the coast of Sumatra, Darwin called attention to the number of seeds carried over from Sumatra and Java. "It is interesting thus to discover how numerous the seeds are, which, coming from several countries, are drifted over the wide ocean. Professor Henslow tells me, he believes that nearly all the plants which I brought from these islands are common littoral species in the East Indian Archipelago. From the direction, however, of the winds and currents, it seems scarcely possible that they could have come here in a direct line. If, as suggested with much probability by Mr. Keating, they were first carried toward the coast of New Holland, and thence drifted back together with the productions of that country, the seeds, before germinating, must have travelled between 1800 and 2400 miles."

One of the most effective means of securing dispersal is that which seems at first glance to be least propitious—that the fruit should be eaten. What seems, for a moment, like a full stop, works well when it works at all, namely, in cases where the seeds are not digested. Succulent fruits are eaten by many birds and by a few mammals; they are eaten for their own sake, and the hard envelopes of the seeds in the case of berries, the hard endocarps of the fruit in the case of drupes, save the seed from being digested. It is passed out from the food-canal none the worse, in some cases probably the better, often, naturally enough, far from the place where the fruit was eaten. In this way we can interpret the occurrence of an isolated gooseberry bush far from any human dwelling.

Some of the modes of scattering are peculiar and rare. Thus the squirrel may forget some of his hidden stores of beech-nuts, and germination may take place. There is some evidence, too, that earthworms occasionally plant trees.

Sometimes the fruit or the seed has some peculiarity which mechanically assists lodgment in the soil, somewhat in the same way as the corkscrew-like automatic boring of the egg-case of the Port Jackson shark effects fixation in a crevice in the rocks. A long bristle or awn in the stork's-bill and some grasses begins to twist under the influence of the moisture in the soil, and literally bores its way in. And again, the wall of the seed or the fruit may have a mucilaginous sheath, as in the case of quince and flax, which effects attachment to the soil, and also serves to absorb water like a sponge. But even more interesting is the adaptation in the pea-nut (*Arachis hypogæa*), whose fruit stalk curves down to the ground and pushes the pod in, reminding one in a quaint way of some animal hiding its egg in the ground. Not less effective is the behaviour of the ivy-leaved Toad-Flax (*Linaria cymballaria*), which beautifies so many old walls. The fruit stalks bend away from the light, which is learnedly called being negatively heliotropic, and the result is that the capsules are actually pressed into the crannies and crevices. A peculiar idiosyncrasy has become the basis of an adaptation that works extraordinarily well, as we may see in watching the rapid spreading of this "Mother of Thousands," as the plant is sometimes called, over a wall or a cliff which seemed anything but a hospitable territory to colonise.

Cases like pea-nut and toad-flax suggest an approximation to what one is tempted to call "parental care," were it not that such irrelevancies of expression are apt to mislead. But they are rare, and certainly far from typical. The big

biological fact which the seed-scattering in Autumn brings home to us is the prodigality and wastefulness of life—such a small proportion of the scattered seeds have any future. As Tennyson said, Nature is "so careless of the single life"; "of fifty," or, as he afterwards suggested, "of myriad seeds, she often brings but one to bear." In spite of all the neat and effective adaptations, it must be said of a large number of species that they succeed not because they are strong, but because they are many. Wallace quotes Kerner to the effect that a common British weed (*Sisymbrium sophia*) often has three-quarters of a million seeds; if all grew to maturity for only three years the whole of the land-surface of the globe would not hold them.

THE WORK OF EARTHWORMS

IN the damp Autumn weather the earthworms drag many fallen leaves into their holes, and we may think over their industry at this season, though there is no time, save when the soil is hard-bound in frost, that they are not busy—boring their way or eating their way underground, grinding the particles small in their gizzards, bringing castings up and taking leaves down, and doing much more besides. In 1777, Gilbert White got at the very root of the matter, and his memorable letter on the subject cannot be read too often. "The most insignificant insects and reptiles are of much more consequence and have much more influence in the economy of nature than the incurious are aware of. . . . Earthworms, though in appearance a small and despicable link in the chain of nature, yet, if lost, would make a lamentable chasm. . . . Worms seem to be the great promoters of vegetation, which would proceed but lamely without them, by boring, perforating, and loosening the soil, and rendering it pervious to rains and the fibres of plants; by drawing straws and stalks of leaves and twigs into it; and, most of all, by throwing up such infinite numbers of lumps of earth called worm-casts, which, being their excrement, is a fine manure for grain and grass. Worms probably provide new soil for hills and slopes where the rain washes the earth away; and they affect slopes probably to avoid being flooded. . . . The earth without worms would soon become cold, hard-bound, and void of fermentation, and consequently sterile.

. . . These hints we think proper to throw out, in order to set the inquisitive and discerning at work. A good monograph of worms would afford much entertainment and information at the same time, and would open a large and new field in natural history."

Long afterwards one who was beyond most men "inquisitive and discerning" did set to work, and the monograph that Gilbert White had wished for in 1777 was published by Charles Darwin in 1881, the year before he died—"the completion," he said, "of a short paper read before the Geological Society more than forty years ago." With his characteristic thoroughness and patience he collected data year after year until he had worked out irrefutably the part that earthworms have played in the history of the earth, and proved that they deserve to be called the most useful of animals. Here we have one of the finest of object-lessons on the cumulative importance of little things.

By their burrowing the earthworms loosen the soil, making way for the plant-roots and the raindrops. By bruising the soil in their gizzards—perhaps the most important mills in the world—they reduce the particles to more useful powdery form. By burying the surface with castings brought up from beneath, they have been for untold ages turning the soil upside down—ploughers long before there was any plough. By burying leaves they have made a great part of the vegetable mould over the whole earth. For, apart from very wet places and very dry places, and salt soil near the sea, there are earthworms of some sort everywhere. We recently found thirteen midribs of the rowan or mountain-ash, radiating round the mouth of one burrow like the spokes of a wheel; the withered leaflets had been carried down, two were still sticking out at the entrance; that meant ninety-one leaflets to one hole, and this has been going on for countless years.

Darwin's statistics are eloquent, but we cannot give more than a few samples. He showed that there are often 50,000 (and there may be 500,000) earthworms in an acre of good soil; that they often pass 10 tons of soil per acre per annum through their bodies; and that they often cover the surface at the rate of 3 in. in fifteen years. Though a common British worm only passes out about 20 oz. of earth in a year, the weights deposited in a year on two separate square yards which Darwin watched were respectively 6·75 lb. and 8·387 lb., which correspond to 14½ and 18 tons per acre per annum. A field which was so thickly covered with hard flints that it was known as "the stony field," was left untouched for thirty years, after which, we are told, a horse could gallop from one end to another without ever striking a stone.

As we follow the work further, additional aspects of importance are revealed. It is plain, for instance, that the constant exposure of the soil-bacteria is bound to have far-reaching effects both for good and ill. On the one hand, it allows the microbes to be scattered by wind and rain; on the other hand, it exposes them to the action of the sunlight, the most universal, effective, and economical of all germicides. In Yorubaland, on the West Coast of Africa, Mr. Alvan Millson calculated (following Darwin's methods) that about 62,233 tons of subsoil are brought every year to the surface of each square mile, and that every particle of earth, to the depth of two feet, is brought to the surface once in twenty-seven years. It need hardly be added that the district is fertile and healthy.

Earthworms also play their part in the disintegration of rocks, letting the solvent humus-acids of the soil down to the buried surface. Their castings on the hill-slopes are carried down by wind and rain, and go to swell the alluvium of the distant valleys or the wasted treasures of the

sea. The well-known parallel ledges along the slopes of grass-clad hills are partly due to earthworm castings caught on sheep-tracks, and thus we begin to connect the earthworms not only with our wheat-supply, but with our scenery.

And as we began this short sketch by quoting Gilbert White, so we shall close it by quoting Darwin. "When we behold a wide turf-covered expanse, we should remember that its smoothness, on which so much of its beauty depends, is mainly due to all the inequalities having been slowly levelled by worms. It is a marvellous reflection that the whole of the superficial mould over any such area has passed, and will again pass, every few years through the bodies of the worms. The plough is one of the most ancient and valuable of man's inventions; but long before he existed the land was in fact regularly ploughed, and still continues to be ploughed, by earthworms. *It may be doubted whether there are many other animals which have played such an important part in the history of the world as these lowly organised creatures.*"

DEEPER PROBLEMS OF MIGRATION.

THE first of the deeper problems is as to the position of migrational movements on the inclined plane of animal activities. Do they imply intelligent control at every, or at any step; is there anything habitual about them, or have they an entirely instinctive basis, that is to say, is the brain endowed by inheritance with ready-made preparedness of a very definite kind for the great annual effort of migration? If we take this last view, there is no reason to increase the puzzle by raising the wider question of how instinctive activities arise at all, for that has no special relevancy to this particular case. Every one knows that the animal world is rich in examples of instinctive activities, for the performance of which, without education or experience, the brain is hereditarily endowed by the establishment of definite nerve-paths or otherwise. Our question is, whether birds have a specific hereditary preparedness for their migratory movements, analogous to that which bees have for burglaring the blossoms and building a honeycomb, or that which spiders have for spinning a complex web?

That the migratory movement has an instinctive basis, is suggested by a number of facts which have a cumulative force, though they are not individually very convincing. Migration shows a regularity and orderliness, without much individuality and with little hint of caprice, which is suggestive of the instinctive; preparations are made for the journey before—often long before—there is any

real need for setting out, and before the wintry conditions have begun to be appreciably felt ; the departure of young birds apparently unguided, and similar phenomena, recall the wonders of untutored instinct among insects ; and a few observations on the restlessness of comfortably caged birds at the proper season point in the same direction. Matthew Arnold has a fine reference to the restlessness of the captive stork when the time comes to travel south, though in his picture the bird is supposed to see its fellows passing overhead.

> " And as a stork which idle boys have trapp'd,
> And tied him in a yard, in Autumn sees
> Flocks of his kind pass flying o'er his head
> To warmer lands, and coasts that keep the sun ;—
> He strains to join their flight, and from his shed
> Follows them with a loud complaining cry "—

Another of the arguments that may be used in support of the conclusion that the migrational effort has an instinctive basis, is that we find somewhat similar periodic movements, from and to a breeding-place, in *widely separated* divisions of the animal kingdom. We find migrations of mammals, of sea-turtles, of fishes, such as the salmon, of land-crabs, and of other types. But it is uecessary to be careful in distinguishing from true migrations—part of the essence of which is a return of adults to their birthplace—certain other mass-movements which are merely outpourings of superabundant population, or enforced pursuits of a nomadic food-supply.

It is a migration when the land-crabs make their quick march, sometimes of several miles, to the sandy coast to have their eggs hatched in the old home, but it is not a migration when the irresistible aerial army of locusts spreads over the land. It is a migration when the salmon and the sturgeon return to breed in their native fresh waters, but it is not a migration when the mackerel shoals

follow the distribution of minute crustaceans in the sea. We recall the march of the lemmings from the Tundra, and from the Scandinavian valleys, where they have become too numerous; they press westward in search of food, through villages, over walls, across rivers, until they reach the North Sea, which solves their population problem But this is no more a true migration than are the invasions of rats and voles that occur every now and then as the result of some unwonted disturbance of the balance of nature.

Among mammals there are not a few records of periodic movements, for instance, among deer, among bats, and among cetaceans, but they do not all fulfil the criteria of true migration. This is illustrated, however, by many seals, though not by our common British *Phoca vitulina*, which travel periodically to their breeding-places.

In accepting the view that migration is instinctive, we do not suppose that this explains much, or that there is no learning to be done. The establishment of an instinct requires analysis just like that of a habit, and there are many instincts that are improved for the individual by experience. We have to avoid the one extreme, well stated and forcibly rejected by Mr. Dixon, that "birds migrate by instinct, knowing not how or why, impelled along a course that never errs or changes, flying from point to point with no more mental effort than an arrow from a bow." The prompting, this author says, is instinctive, but there is much that the bird has to learn. The instinct is very variable and often imperfect, for "birds blunder like human folk, losing their way, and perishing in uncounted hosts." We have to avoid the other extreme of supposing that a successful migratory journey is the outcome of sensory alertness and good judgment. Somewhere between these two extremes the truth probably lies. There is a migratory

instinct, part and parcel of the bird's inherited constitution, and doubtless varying in precision and in content in different birds. But it is not inconsistent with this to believe that keen senses, quick perceptions, good memory, obedient following of leaders, and a sense of direction, are also of great importance. We have ourselves so few instincts that it is difficult for us to get mentally near creatures in whose life instinctive activity bulks largely, but we need not suppose that the migratory instinct is isolated from the bird's highly evolved sensory life, or from its undoubtedly good memory.

If we start right away with the astonishing migrational movements of the knot or the curlew-sandpiper, and assert that these have an *instinctive* basis, we may be accused of escaping from a formidable difficulty under the shelter of a word. But in evolutionary interpretation this impression always arises when we begin by thinking of the most elaborate and finished product, instead of the simplest possible illustrations. If we are thinking of the problem of the evolution of the eye, we should not begin with man's or the eagle's; if we are thinking of the problem of the evolution of sex, we should not begin with the elaborately finished dimorphism of peacock and peahen, but with cases like sea-urchins, where it requires a microscope to tell the male from the female. So in regard to migration, we may reasonably begin with the short migratory movements, say of blackbirds, which are relatively simple affairs.

If we are convinced that there is warrant for speaking of a migratory instinct, we may pass to the next question, *What conditions led to the establishment of this instinct?* When we think back imaginatively to the beginning of migration, we see the emergence of a new idea, which is called, in the technical language of Biology, a mutation. A new constitutional type arose—the revolutionary, who

would not take hard times lying down, who was sensitive, alert, restless, unconventional, adventurous, and original, who was a genius, in short, a Columbus-bird.

To meet a difficulty—such as hard Winters—there may be detailed readjustments of what has been already established; the plumage may turn white, for instance, which always helps, or a thick layer of fat may accumulate beneath the skin. But there is another way of meeting a difficulty,—by evading it altogether, and that requires genius, and that was how migration was started by a number of highly original birds, who discovered that the prison-doors were open, and who thought it was worth while trying whether Land's End in Cornwall or elsewhere was really Land's End.

All living creatures tend to flee from the uncomfortable, and it is evident that, as the earth and the bird are constituted, things are against permanent residence in one place. Moreover, in the course of the evolution of climates, since birds began to be, there have been successive glacial periods in which the Northern Hemisphere was certainly not a fit winter-residence for birds, and for long ages not a fit home for birds at all.

The greater part of the Northern Hemisphere once had a much warmer and more equable climate than it now enjoys. There were magnolias blooming in Greenland and palms flourishing in England as they still do in mild places like Penzance. It was perhaps relatively unimportant to birds where they went, though they would tend to get away from the hotter regions at the breeding and brooding time, and would move southward from the more exposed northern outposts when Winter came. But as the climate became gradually more severe, and the snowline crept lower and lower on the mountains, and great glaciers were formed, birds had to move farther and farther south every

half-century. In many cases it became impossible to return to the old home in Spring. The whole of Britain, for instance, was probably ice-covered, except a narrow stretch along the South of England. Those birds that could not endure the more southerly breeding and brooding would be eliminated, those that were slow to recognise the menace of approaching Winter would be eliminated, and those that had no sense of direction would be eliminated, and the migratory instinct would diffuse itself and become more and more precise.

After the Ages of Horror were passed and the ice had in great part retreated to the Polar Regions, there came about what we may still see continuing—the recolonisation of the North Temperate Zone as a breeding area. At the present time there are some birds, such as starlings, which are pressing farther and farther northward year after year. In connection with this return to old racial haunts which the Ice Age had rendered quite unhabitable, we must remember that other climatic changes were probably in progress which made the South a more and more difficult region for secure breeding and successful brooding.

In general terms, then, the present-day Spring migration northwards implies an organic reminiscence of the original headquarters before the Ice Ages; and the present-day Autumn migration southwards implies an organic reminiscence of the second home which was discovered under the stress of the glacial invasion. And the paths of the migrants to-day may still correspond in some measure to those established by slow degrees as the ice flowed and ebbed. It is certainly very significant that many birds from the Continent should cross to the South of England in Autumn and then curve farther southwards—in this way visiting the tract of Britain which was not covered by the ice.

Our view, then, is this, that an original instinctive Mutation must be postulated, which amounted to "a new idea," but was not an idea, which found expression in restlessness, in sensory alertness, in adventurous experiment, in a "Wander-trieb." Perhaps we see something like the beginning of it to-day in animals which seem to be sensitive to impending storm, and act accordingly. But given some sort of definite beginning of a migratory instinct, as a germinal mutation, we would account for the diffusion and augmentation and specialisation of this by the well-known Darwinian interpretation, especially elaborated by Dr. Alfred Russel Wallace. Those individual birds who were too dull, or too wilful, or too unplastic, to take the hints and warnings of the increasing scarcity, the cold winds, or it might be the dry heat, would be eliminated. This elimination, still a dreadfully real process, would, being discriminate, gradually raise the standard of migratory capacity century after century, millennium after millennium, for we must bear in mind that the great climatic changes must have come about with extreme slowness.

Another general theory of the conditions which led to the establishment of a migratory instinct, lays the emphasis on the food-supply. Many birds are prolific, and overcrowding is apt to occur. They have to extend their range, and they take the lines of least resistance as regards food. They push northward in spring, exploring new grounds, staying as long as they can, and retreating before the Winter to the original home. Instead of crowding in one area all the year, and involving themselves in want, they exploit two areas, each for about half of the year. We see the same sort of thing among men, for instance, in the Summer migration to the high "alps," and the return in Winter to the village in the valley. It has often been

pointed out that the more prolific birds tend to have the wider migratory range—a fact which fits in well with the theory outlined. We venture to quote a statement of the case from Mr. W. P. Pycraft's excellent *History of Birds* (1910):—

"We may assume that the migratory species owe their origin to the matter of food-supply. Composed of individuals subsisting on a food of universal range, but limited in supply, they were enabled to roam farther afield as their numbers strained this supply in their immediate neighbourhood. Annually, however, a check was placed on further extensions of range by the cares of breeding, and by the diminution of food at the end of the breeding season,—whether caused by climate or otherwise,—while behind them the supply was increasing. Thus they were drawn back towards their starting-point. Again threatened by famine, they once more turned outwards, finding the earlier depleted area restocked. These movements, in short, were doubtless then, as now, periodic, and determined largely, if not entirely, by seasonal changes. Such species, increasing numerically with their increase in range, were naturally automatically compelled to still farther extend this to obtain the means of sustenance. That each individual would return by the route he came by is but a natural inference, and the same is true of the offspring of each pair—hence the 'homing instinct,' and the formation of British or other races of migrating species."

Dr. Alfred Russel Wallace has laid emphasis on the abundance of food in the Far North as a factor in establishing migration. He quotes Mr. Seebohm: "Birds go to the Arctic regions to breed, not by thousands, but by millions. The cause of this migration is to be found in the lavish prodigality with which Nature has provided food. Seed- or fruit-eating birds find an immediate and abundant

supply of cranberries, crowberries, and other ground fruit, which have remained frozen during the long Winter, and are accessible the moment the snow has melted, while insect-eating birds have only to open their mouths to fill them with mosquitoes." The vast hordes of mosquitoes (which do not seem to trouble birds) and their larvæ swarming in the pools seem to account for "the very existence of a considerable proportion of the bird-life in the Northern Hemisphere."

Dr. Wallace goes on to say: "Abundance of food suitable for both parents and young at the season of breeding would inevitably attract birds of all kinds from more southern lands, especially as the whole area would necessarily have no permanent residents or very few, but would, each recurring season, be an altogether new and unoccupied, but most fertile country, to be reached, from any part of the North Temperate lands, by merely following up the melting snow. And as, a few months later, the myriads of young birds in addition to their parents were driven south by the oncoming of the cold and darkness, they would find it necessary to travel farther and farther southward, and would again find their way north when the proper season arrived."

We have stated two theories of the origin of migration. Neither is very convincingly complete by itself; perhaps a combination of the two is best.

Immediate Stimuli of Migration

The next question is as to the immediate causes which now pull the trigger of the migratory instinct twice a year at the proper time. In the case of the Autumn movement southward, we naturally think of (*a*) the increasing cold and the lack of shelter, (*b*) the setting-in of

stormy weather, (*c*) the marked shortening of the daylight hours available for food-collecting, and (*d*) the dwindling supply of insects and slugs, fruits and seeds, and the like. In one or more of these external conditions we may perhaps find sufficient liberating stimulus to set the migratory instinct at work.

In many ways the return Spring journey to the birthplace is more difficult to understand than the Autumnal journey southwards. The stimulus may be the setting-in of dry heat, or uncomfortable weather of some sort, or the shrinkage of the water-pools, and there is the awakening or re-awakening breeding instinct. On the other hand, a large proportion of the birds who undertake the northerly journey in Spring are immature, and cannot be prompted by any breeding impulse. Again, though one cannot wonder that birds should like to get out of the heat and the crowd and the multitudinous enemies of lower latitudes, we cannot shut our eyes to the hazards of nesting in the Far North. The young bird, as we have seen, is for days after hatching very imperfectly warm-blooded, and cannot be left exposed for even a short time without fatal results. It is probably the constitution of the bird that makes it necessary for some to go so very far north, just as the eels are constitutionally impelled to go far out and far down into the Atlantic. Perhaps in both cases the constitution was established in relation to the conditions of the ancient headquarters, the old home of the stock. Thus there may be a constitutional home-sickness, though no psychical one. There is no warrant for supposing that the Knot has a "fond memory" for its birthplace in Northern Siberia. Although Professor William K. Brooks suggested that the north-bound Spring migrant who ignores so many choice spots on its route, may be like "The shuddering tenant of the frigid zone," who "Boldly proclaims that happiest

spot his own," we are not inclined to go beyond the hypothesis of a visceral *Heimweh.*

We must not press these considerations too hard, as if living creatures were inert balls buffeted here and there by sheer compulsion. The reasons we have given for the autumnal and vernal movements are impelling rather than compelling, they operate on constitutional predispositions. There are notable difficulties remaining, and curious individual exceptions, such as that of the cuckoo. Therefore let us turn for a moment, all unsatisfied with explanations, to enjoy the mysteriousness of this vital tide, agreeing with Gätke that "both phases of the great movement unfold a picture of bird life of incomprehensible grandeur, presenting to our wondering sight myriads of these restless wanderers hastening during the long dark nights of Autumn, or the starlit midnight hours of Spring, by many intersecting paths, to their far-off Winter quarters or their nesting homes; each species following, at higher or lower regions in the sky, a sure and definite road, not marked out for them along river courses or mountain chains, but one that leads them, independent of every physical configuration of the earth's surface, and at heights many thousands of feet above it, surely and safely to the distant goal."

This brings us to the question, How do the birds find their way? It is our strong conviction that before naturalists will make much of a question of this degree of difficulty there will require to be many years of hard work at much less exciting questions, such as *What way do they find?* At the same time, it is very interesting to raise the very difficult question of way-finding, and to consider the suggestions that have been offered.

> "Who calls the council, states the certain day,
> Who forms the phalanx, and who leads the way?"

How is it that a swallow which has wintered in Africa comes back to its birthplace in the South of England? How is it that young birds, who never left the parish before, start off on a Summer evening and make their way to the Nile Valley? How do they keep their direction in the dark and at great heights, or do they very often go very badly astray? If it be true that the northward-bound Spring migrants often take a short cut, different from their Autumn journey south, how is this to be thought of? Sailing northwards from the Cape by the West Coast route one meets in Autumn numerous migrants making their way south. Many of these rest for hours on the ship, but most of them certainly continue their southward journey. Why?

a. It has been suggested that success in way-finding may be due to inherited experience, slowly cumulative from generation to generation, enriched and specialised by individually minute contributions. There are two great difficulties in the way of this theory. In the first place, we have no secure warrant for believing in the direct entailment of the lessons of experience. In the second place, it is difficult to see what *content* the experience could have in the case of birds flying by night, and often at great heights, as so many do.

b. A second theory attributes the success of the migratory effort to tradition, and there may be some truth in this attractive suggestion. The idea is that those lead well one year who followed well for several years before. There may be in each rushing troop some old, experienced guides. Again, however, there are difficulties. Every individual experience must have a content of definite and concrete impressions, but what precise experience is to be had out of a night journey at a high altitude over the pathless sea? If we begin by traversing a difficult and

dangerous path by daylight and establish a detailed experience, we can afterwards proceed, in a very interesting way, to strip off one aid after another, until we can walk safely on a very dark night with only a white stone, or something of that sort, here and there to guide us. But there is no evidence that birds *learn to find their way* after the fashion we have just indicated. Moreover, there is the difficulty that the young birds seem often to fly by themselves. In the case of the cuckoo there does not seem to be an adult left in the country when the young ones leave us in Autumn. But it is not known that they are less successful than other birds.

c. A third theory attributes the success of migratory way-finding to sensory acuteness, and it seems likely that there is some truth in this view. Numerous observations show that migrants *sometimes* follow coast-lines, river-valleys, lines of islands, and so on. We need not attend to stories of birds following the roll of the waves, or guiding their course by the stars, which are not scientifically much above the level of the suggestion that they utilised the lines of longitude, but the visual and auditory powers of birds are so keen that we should be slow to exclude the possibility that they utilise all possible landmarks.

d. In the dearth of facts, the tendency of the scientific mood is to leave a question of this sort quite unanswered, but to those who feel the necessity of coming to *some* finding—albeit a provisionary one—we should recommend the hypothesis of " a sense of direction," to which various considerations point. There are many hints of this mysterious sense in other animals. We know it in cats and dogs, in cattle and horses, of whose way-finding powers in most intricate situations there is abundant evidence. It has been satisfactorily proved in bees. There are apparent illustrations of it in nomad human races and in exceptional

civilised men, like the hero of Du Maurier's *Martian*, who always knew where the North Pole was, when he was in good health at least.

The "homing" of pigeons is very suggestive in this connection. They may be transported in a basket by train or steamer and set free many miles from their dovecot—and they are usually soon home. According to Tegetmeier, an acknowledged authority, the power is mainly the outcome of great sensory acuteness, and requires training if the birds are to excel.

Professor Newton spoke of the migration of birds as "perhaps the greatest mystery which the whole animal kingdom presents—a mystery which attracted the attention of the earliest writers, and can in its chief point be no more explained by the modern man of science than by the simple-minded savage or the poet or prophet of antiquity." But this was perhaps too pessimistic. Admitting that "our ignorance is still immense," may we recognise some hints of progress towards greater clearness. We are slowly learning to sift our data and to put our questions in more useful form. Three methods have been followed with much success. The first, associated especially with the name of Gätke of Heligoland, is that of registering the arrivals and departures of birds on a small area that can be thoroughly explored. The second, associated especially with the name of Eagle Clarke of Edinburgh, is that of collecting data from lighthouses and lightships and similar strategic points as to the annual streams of migrants. The third, associated especially with the name of Thienemann of Rossitten, is that of marking birds with numbered aluminium rings and registering the whereabouts of those (a small percentage) that are heard of again.

THE STORY OF THE SALMON

THE whole of this story is not yet told, and what there is of it equally good observers tell in somewhat different ways. But these are not sufficient reasons for severely leaving it out of our seasonal chronicle. The broad facts are certain, though uncertainties still abound. They are largely due, we think, to the fact that this much-esteemed, but intellectually defective fish has in no small degree an individuality of behaviour and a plasticity of constitution. Its freshwater environment, moreover, is very diverse, for every river has a character of its own. What is to be avoided is forcing a formula on the salmon.

We might include the story of the salmon with appropriateness at almost any season, but we have taken it as an autumnal study for two reasons, because our best views of the salmon surmounting a fall (is not this what their very name points to ?) have been got in Autumn, and because salmon spawn in British rivers in late Autumn or Winter. One of the leading authorities [1] states the law for Scotland, that " the height of the spawning season in the earliest river, viz. 7th November, is one month earlier than the height of the spawning season in the latest river, viz. 8th December."

The salmon's eggs are laid in the gravelly bed of the stream in shallow water. The female makes a furrow for them with her tail, and covers it roughly after her attendant mate has shed upon them the fertilising milt. One female

[1] W. L. Calderwood, *The Life of the Salmon* (1907).

may go on depositing eggs at intervals for several successive days, and the rival males fight with one another fiercely for their place in her train. The hooked and somewhat distorted jaws of big males seem to be adapted as weapons.

The eggs have many enemies, such as trout, eels, waterfowl, and insect larvæ, which have plenty of time to find them out, for three or four months must elapse before they are ready to be hatched. There are many other risks of failure; they may be left exposed by a great drought, or washed away by a flood, or smothered by a shifting of the gravel. It need hardly be said, therefore, that only a small proportion of the eggs become "fry."

The newly-hatched young are very sluggish, and lie among the stones, living on their legacy of yolk, which may last for fifty days. It lies in a ventral sac, which rather inhibits the little creature's movements. About the eighth week after hatching, the yolk has been wholly absorbed, and the larvæ, or "fry," are about an inch long. They begin to feed greedily on minute organisms in the water, they grow quickly (in marked contrast to their slow development), in two months they double their size, and by the end of a year they are somewhat trout-like "parr," about four inches in length. It is interesting to recall that it is only some seventy years since Shaw, at Drumlanrig, proved that the parr is the young salmon, and not a member of a supposed related species (*Salmo salmulus*) of diminutive size.

In their second year (in most cases) the young salmon lose their trout-like markings and put on their "sea-jacket"—tints of olive and gold overspread with glistening silver. In other words, they become silvery "smolts," which migrate to the sea. The descent of the smolt to the sea, Mr. Calderwood writes, "is prompted by a most powerful

instinct. Give fish in confinement as much and as carefully selected food as they can eat, and the silvery smolts are in no way induced to forego their seaward migration. For the healthy growth and development of the species salmon, as we now know it, the bracing qualities of the sea, with its rich feeding, are absolutely necessary."[1] . . . "We have no evidence that smolts would starve in any of our rivers if they did not descend when they do. No doubt they get a greatly increased and varied amount of food when they do go into the sea, but the time when the migration takes place is the time when the best feeding season is commencing, and it seems to me necessary to take the natural instinct for a temporary marine sojourn into account as well as the need for increase of food." The descent of the smolts is mostly in Spring, and they are often about six or seven inches long when they put on their "sea-jacket."

The smolts that are successful in making the journey to the sea—for they have to run the gauntlet of many dangers—enter upon a course of voracious feeding which lasts for a variable period. They devour young herrings and haddocks, the eggs and larvæ of crustaceans, and so on, and grow apace. At the same time, the thinning of the crop continues, for a new set of enemies has to be faced—gulls, cormorants, coal-fishes, and the like.

It is a common belief that salmon-smolts, descending to the sea in April or May, may return as "grilse" in June or July of the same year, and it is likely enough that this is sometimes the case. On the other hand, smolts marked by Malloch in 1905 returned as grilse in 1906.[2] Moreover, if it be the case that the character of the lines on the scales

[1] *The Life of the Salmon*, by W. L. Calderwood, Inspector of Salmon Fisheries for Scotland (Arnold: London, 1907).

[2] P. D. Malloch, *Life-History and Habits of the Salmon, Sea-Trout, Trout, and Other Fresh-Water Fish* (A. & C. Black, 1910, 263 pp.).

may be relied upon to show how often a salmon returns to fresh water, then Malloch's conclusion seems secure that many skip the grilse stage altogether, and do not return till they are salmon. If the assumption be granted, then many of the smolts marked in 1905 returned as small Spring salmon in 1907, and many came up the Tay in the following year, from 20 to 40 lb. in weight, without having been in fresh water since they were marked. In any case, it may be safely said that the smolts are moved by a strong impulse to go to the sea, that they feed voraciously and grow quickly there, and that they return sooner or later to spawn. Most, if not all, of the energy which the salmon show in ascending the swift streams, and in leaping up the falls, is accumulated during the variable marine period. For after youth there is practically no feeding in fresh water.

Again, as in so many other cases, we have a sharp antithesis between a feeding and growing period on the one hand, and a fasting and reproductive period on the other hand. It is the antithesis of caterpillar and butterfly over again; but how different the guise! Few salmon seem to spawn more than once, and some die of spawning. After the exhausting process, they are known as "kelts"—thin and lanky, and out of condition. They return to the sea, regain their tone, and eat ravenously. It is certain that some live to a good age, for giants of 55 and 60 lb. have been caught with the rod, and even larger ones in nets.

There are serious discrepancies, both of observation and interpretation, in the current accounts of the life-history of this very common creature. As we hinted at the outset, the probable reason for this may be found in the variability of the organism on the one hand, and in the diversity of its environmental stimuli on the other.

We must bear in mind, however, the broad fact that the salmon is what one might call a " bimodal " organism. As an adult it has its consistently ascetic, freshwater period, with the single orgasm of reproduction, and its consistently Epicurean, marine period of nutrition. Punctuated by the seasons, though, for the reasons stated, with important exceptions, there is an almost diagrammatic contrast between the nutritive and the reproductive phases.

AGAINST THE STREAM

THE river was in high flood, and the salmon were pressing up it. They had been out to sea, and were lusty; it was a sight to watch them leaping high into the air over the first step of the salmon ladder, dashing ahead with strong tail-strokes, and rising rapidly to the top of the fall. Their hunger was swallowed up in love, for fishes love—as fishes can. To put it in another way, they were making for the spawning-ground, and they were fasting. One recalls that many momentous changes occur during fasting periods. For it is when fasting that caterpillars become butterflies, and tadpoles frogs. Thus there is a biological justification of asceticism, although "Der Hunger als förderndes Princip" (as the Germans phrase it in their inimitable fashion) may be carried too far. There is also apt to be a strange unconscious hypocrisy about it, too, for the caterpillar is quietly absorbing its "fatty body," and the tadpole its tail — which is a luxury after all.

To return to the salmon at the fall. The lithe body, less silvery than usual, shot out of the water; then followed a plucky rush amid the bubbles; then in seven cases out of ten the fish was swept back before it had cleared the second rung of the ladder. It was as exciting as a racecourse. The favourite cleared one barrier after another, lost energy at the last, and was swept back like a log, while another with less dash about him cleared every one, and shot ahead

in the swift, smooth, sullen water above the fall. There was pathos in the passiveness with which the unsuccessful swimmer let himself be swirled back to the eddies at the foot of the ladder. Like a spent horse, he could no more; but one knew that he was setting his teeth, so to speak, for the next rush. One wished to know many things—whether the males or females got up first, whether it had become a matter of course to the old salmon, how often the young grilse required to try, and how they felt when they were baffled.

There are many ways of looking at such sights. The practical point of view was well represented by the crowd of town's boys. How many of them had "cleeks" n their trousers, no one could tell; but there were rumours of a suspicious abundance of appetising fish-suppers in the town. Probably the Game Laws do express a certain sense of the sportsmanlike, and it seemed a shame to cleek a "breathless" fish which a side current carried shorewards. Yet as their fathers and grandfathers had held these to be part of the year's spoil, the youths naturally resented any attempt to prevent them from doing what had always been done. And there were many fishes, for we were able to count fifty-one leaps in a minute. It is easy to be "moral" about poaching after a good breakfast, but what would the natural man have done had he been hungry? There is delight in the cutlets of even a fasting salmon, and there is a monotony about porridge and respectability.

The erudite scientific person was also represented. He did not care for salmon-cutlets. Protoplasm and the centrosomes for him! Given, he said, the force of the current, given an integrated aggregate of complex molecules (called for convenience *Salmo salar*), with an inherited nervous mechanism, explosive muscle-cells, and all the rest

of it, and the leap of the salmon is a function of the velocity of the water and the metabolism of the fish.

$$L=f\left(\frac{v}{\mu}\right).$$

This is true in a way, but it is hardly the whole truth. Unless μ be taken to mean more than is usually granted, it is a dull, one-sided fact. One misses in the formula any recognition of the fact that the fish is also a spirit—a water-sprite. It has a consciousness, an experience, some sort of mental life, strong desires, and that byplay of activity which we call emotion. It is a personality of a fishly sort. We must admit that it cannot reason, this *Salmo salar*; its intelligence is of a low order; but if it thinks little, it feels much; it is a water-baby. What surmounts the fall is no torpedo, no automatic machine—that idol which modern man projects upon Nature; it is a creature with a history—a unified history—remembering its cradle, liking, in a cold-blooded way, its mate, enjoying its struggle against the angry strength of the river.

There is no excuse for the naturalist who forgets to-day what was said so long ago—"All flesh is not the same flesh: but there is one kind of flesh of men, another flesh of beasts, another of fishes, and another of birds"; and we do not forget. But there is more than one touch of flesh which makes the whole world kin. To name one, phrase it as you please, it is the genetic impulse that calls the salmon, as it calls us. The melody is personal, varying with each grade of being, but the motif is universal.

Phenomena are all very well, but why not see them also as noumena *sub specie æternitatis*? Then the salmon pressing up the stream, careless and thoughtless if you will, but feeling the living hand of the past upon them, feeling the promptings of the present—vague analogues of what we call "love"—dimly perceiving the waters far ahead where

last year they found pleasure, become prototypes and emblems of the great endeavourers who are the centres of our hero-worship—even of those

> "Who, rowing hard against the stream,
> Saw distant gates of Eden gleam,
> And did not dream it was a dream."

BOOK IV.—WINTER

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IMPRESSIONIST SKETCH

I

A TRUE judgment as to the vital import of a Northern Winter is not altogether easy for us, here and now. It is not so easy for us, apart from our science, as it was for our ancestors, for we have become more and more cunning in ignoring Winter. What was in early days expressed in shelter, a fire, warm clothes, and fatty food has become a fine art with us. It is not so easy here as it is farther North to realise the Winter, for, in spite of all our grumbling, a British winter is usually a mild affair. It is not so easy now as it once was, for even our worst winters are but far-off echoes of the Glacial Epoch, when Winter not only conquered Summer in the annual contest, but remained victoriously dominant throughout the year, and for long ages. Thus it is evident that to do Winter justice we have need to question the Lapps and Samoyedes and other dwellers in the Far North, or, where these have not voices that we can understand, explorers like Nansen and Peary; we must think of the Polar Regions, of Alpine life above the snow-line, or of that dark, silent, plantless, intensely cold world—the Deep Sea—where the spell of Winter is unrelieved and perennial; and we must let our imagination travel back to the Ice Ages—the Ages of Horror—during which whole faunas shuddered. Unless we make some such efforts, which we can only suggest,

we are likely to estimate the power of Winter too lightly, and fail in seeing to what degree it casts a spell, often a fatal one, upon life.

Let us put it in another way: To realise what Winter may still mean for us, we must leave the city and visit the open country, especially to the North. We must see, not the gaiety of the artificially heated town, but the frozen fiord; not men muffled up in beaver coats, but the beavers themselves in their frozen dam; not the winter-garden, but the trees in a garb of ice; not the cattle chewing in their stalls, but the dead birds lying under the trees.

II

A true appreciation of Winter was long since expressed in the story of the Sleeping Beauty. She was richly dowered with vigorous beauty and joyous grace, but all her gifts were shadowed by the foreboding of early death. This doom, however, was transmuted into a kinder spell, which bound her to sleep, but not to dying. All care notwithstanding, the spindle pierced her hand, she fell into deep sleep, whence at last the Prince's kiss served for her awakening. Various commentators apart, the meaning is plain: The Princess was our fair earth with its glow of life, her youth was Summer—often shadowed, the fatal spindle was the piercing cold, the spell-bound sleep was Winter's long rest, the kiss that awakened was the first strong sunshine of Spring. The beautiful old story is literally one of the "fairy-tales of science."

In the same way, though there is much else in the myth, Balder the Beautiful represented the virility and vitality of the sunny Summer; and the twig of gloom, the mistletoe, which flourishes and fruits in Winter, and was fatal to Balder, was the emblem of the freezing cold which

so often brings sudden death or the quiet peace of sleep. A similar interpretation holds for the subtle story of Proserpine.

III

But let us turn from fancy to fact, though, perhaps, there is sometimes more trueness to Nature in the fairy-tale than in scientific text-book. The astronomers tell us of the general law that on either hemisphere 63 per cent. of the total heat of the year is received during Summer and 37 per cent. in Winter; but this statement, fundamental as it is, hardly expresses the full force of the case. For the astronomers are thinking, and, from their point of view, rightly, of a year with only two seasons; therefore, as we are dealing with four, we must refer part of the 37 per cent. received in Winter to late Autumn and part to early Spring, leaving Winter poor indeed.

The same authorities also tell us that the length of Summer and Winter is variable; thus we have now about 186 days of Summer and 179 days of Winter (in the two-season sense), while it is but a geological yesterday since in the Ice Ages the Summer lasted for only 166 days, and 199 lay in the grasp of Winter. This is again very important, for the total amount of warmth received has obviously to be divided by the number of days in the season to give us a numerical expression of the average daily sun-heat at any given time. Yet, finally, this must not hide from us the commonplace of experience that it is not the average temperature which, so to speak, says yea or nay to this or that form of life; it is rather the occurrence of certain maxima and minima—a terrible heat-wave or a week of very frosty nights. After one exceptionally cold night some years past, over two hundred birds were found dead round the stacks in a small steading.

IV

To the cold and the scarcity of food which Winter involves in this and more northerly latitudes there is great variety of response or reaction on the part of living creatures. Of this variety let us take a few illustrations. Thus most of our birds, emblems of freedom, escape the spell by flight; and, though death is often fleeter still and overtakes them by the way, there can be no doubt that the migration-solution is an effective one. Literally, they have no Winter in their year. Among those partial migrants who are hardy enough or foolhardy enough to risk remaining with us in Winter the mortality is often disastrously high. Winter after Winter may be weathered, and then, as we have already noticed, there may be a severe thinning of the ranks.

Other creatures, unequal to the long and adventurous journeys of the birds, retire into winter-quarters, in which they lie low, awaiting happier days. Thus the earthworms burrow more deeply than ever below the reach of the frost, the lemmings tunnel their winding ways beneath the icy crust of the Tundra, all manner of insects in their pupa-stages lie inert within cocoons or other protective envelopes in sheltered corners, the frogs bury themselves deeply in the mud of the pond, and the slow-worms coil up together in the penetralia of their retreats—all trying to get below the deadly grip of the frost's fingers.

Others, again, such as the Arctic fox, the mountain hare, the ermine, the Hudson's Bay lemming, and the ptarmigan, face the dread enchantment of Winter, but turn paler and paler under the spell, until they are white as the snow itself—a safety-giving pallor. They have a constitutional tendency to change their colour, and the external cold pulls the trigger that sets the process at work. It is well

known of Arctic fox and mountain hare, for instance, that the degree of whiteness varies from year to year with the intensity of the Winter. As for its utility, this is, at least, twofold—the white dress is of service in the chase or in flight, while, on the other hand, it is the most economical and comfortable dress for a warm-blooded animal when the external temperature is very low.

Man, himself, gets inside other creatures' skins and bids defiance to weather, or, having in his cunning tapped one of the earth's great stores of energy—a coal-bed—sits comfortably by his hearth, gloating in what is really the warmth of a larger sun than that which now sends him in the wintry months too little cheer. But his indifference to the Winter has, in part, a very precarious basis, as a prolonged coal-strike shows ; it is, in part, a privilege of the few, as a glance along our streets suffices to prove ; it is, in part, merely local, as a short journey northwards may convince us. Man, too, like the birds, often migrates even from our British mildness to a sunnier South, and he knows, like many a creature of less high degree, of winter-refuges, whether in a poorhouse at home or a "pension" abroad.

V

To many organisms, both of high and low degree, the alternative comes—to sleep or die. The spindle cannot be escaped, the cold shall pierce like a sword—but sleep ! and it may be well. Of this "sleep" there are, indeed, many degrees, from the mysterious latent-life of frozen seeds and animal germs to the almost equally mysterious true hibernation of marmot and hedgehog. Often, too, it must be admitted that what began in slumber ends by becoming sleep's twin sister, Death. Yet we understand so little of these more or less dormant states in their rela-

tions to one another, or, indeed, of any one—even sleep—by itself, that we must be content here to use the word somewhat loosely when we say that Winter is to many forms of life a sleep-bringer.

The great hypnotist lifts his hands, and the sap stands still in the tree, and the song is hushed in the bird's throat; he makes his passes, and growth ceases in bud and seed, in cocoon and egg; he breathes, and sleep falls upon marmot, hamster, and hedgehog, upon tortoise, frog, and fish, upon snail and insect; he commands—his voice is the North Wind—and the water stands in the running brooks, and the very waves of the fiord are still. Even in our own mild country, is not the freezing of a considerable part of Loch Fyne upon record?

Apart from the state of latent life—in which a paste-eel, for instance, may lie neither actively living nor really dead for fourteen long years, and seeds for several decennia, though not since the days of the Pharaohs—there is no form of sleep so near to death as this to which the Wizard of the North commands the true hibernators. Somnolence penetrates to the deepest recesses of the creature's constitution, as the expert histologist has shown us in his fine study of the minute structural changes observed in the cellular elements of the sleeping hedgehog.

The heart of the hibernator beats feebly and somewhat irregularly, the breathing movements are at long intervals and very sluggish, the food-canal is empty, income is (apart from oxygen) at zero, and expenditure is but little more. The sleeper may be immersed in water for twenty minutes, or subjected for some time to noxious gases, but without apparent effect in either case. The fat, accumulated in days of plenty, is slowly burnt away, sustaining in some measure the animal heat. In the warm-blooded mammal the normal power of keeping an approximately

constant body-temperature is in abeyance for a time, and the body cools to a degree which in ordinary life would be fatal; irritability wanes to a minimum; the ordinary reflexes are at most faint, and the creature steadily loses weight. The real wonder is that it keeps alive.

The slumberers differ much in the soundness of their sleep. Thus there are light sleepers, like the dormouse, the harvest mouse, and the squirrel; and heavy sleepers, like hedgehog, hamster, and marmot, or like the tortoise, whom the crack of doom would scarce disturb. But it and all other sound sleepers must yield to the snail who overslept himself so far that when he awoke it was in a case in the British Museum, wherein he bore a ticket already many years old. There was another Rip Van Winkle snail who awoke to find himself an extinct species; but that, as they say, is another story!

After we allow for the tendency that cold has to produce coma, of which Alpine travellers have told us tales, for the drowsiness which is said—let us hope it is true—to take the edge off starvation, and for the sleepiness induced, *e.g.*, in church or lecture-room by confined atmosphere, of which no proof is required, there seems to be need of further physiological explanation. It has been shrewdly suggested that the retention of waste-products during hibernation induces a state of "auto-intoxication"—a drugging or poisoning of the system with its own excretion, a banking-up and smothering of the fire of life with its own ashes. It seems a plausible view that this will tend to keep the sleepy sleeping, and the idea may be hazarded that one of the reasons why plants are not more wideawake is just this retention of nitrogenous waste-products. For it is well known that plants do not get rid of these. The same is in a measure true of the sea-squirts

or Ascidians, which in their adult life are sedentary and sleepy animals, curiously plant-like in a number of ways, notably in the mantle of cellulose which invests the body.

The general import of hibernation is in most cases plain. Life saves itself by ceasing to struggle, by retiring within its entrenchments. Death is baffled by a deep device, in which activity virtually ceases without life itself being surrendered. Hibernation is the finest organic illustration of the policy of "lying low."

Yet there are other aspects of the Winter's sleep. To some it is a time of repair—a long night—after the nervous fatigue of a long day. Thus it is not difficult to understand that, quite apart from the weather, it is good that the queen humble-bee should sleep through the Winter, just as it is well for the fisherman that he should loaf after the storm. In short, we return to our main thesis, that life is rhythmic, and that the seasons punctuate it.

To others the sleep is in some measure a preparation for a new day. Thus in the seeds which slumber in the earth, each a young life, there is a rotting away of the husks which the delicate embryo could scarce burst, and later on there are processes of fermentation, by which the legacy of hard, condensed food-material is made available for the young plant. That it is not merely the unpropitious weather and the hard soil which make it necessary for the seeds to remain asleep may be proved by experiment, and it is also proved by the fact that not a few normally lie dormant for several years. Similarly, within the cocoons there lie the chrysalids, quaintly mummy-like and inert to all appearance, but slowly undergoing that marvellous transformation, the result of which is the winged butterfly—the Psyche.

VI

It seems a true paradox that one of the great facts in the Biology of Winter is the frequency of Death. Not that there is any season when Death is not busy, or any opportunity which he does nor seize; he picks and chooses among the newborn of the early Spring, he lays pitfalls for the adolescent, he thins the ranks of Summer's industry, he puts in a full stop at the limit of growth, he forces open the door which Love seeks to keep closed, he harvests in Autumn; but it is in Winter that his power is most felt. It is the time of least heat, least light, least food, and, therefore, of least resistance and lowest vitality.

The influence on plant-life is most obvious and direct; a large fraction of the income of radiant energy is cut off, the water-supply is also reduced, and there is further risk that the frost cause bursting of cells and vessels within the plant just as in our houses. The diminished vigour of plant-life means less food for the animals, and on them, too, the relative lack of warmth and sunlight has a directly disastrous effect. Given, as Shelley pictures,

> "A winter such as when birds die
> In the deep forests, and the fishes lie
> Stiffened in the translucent ice, which makes
> Even the mud and slime of the warm lakes
> A wrinkled clod, as hard as brick,"

the decimating influences are perceptible on every side. Thus after a hard Winter there is eloquent statistical evidence forthcoming of the mortality from moor and forest, lake and seashore. Winter is indeed a time of rest and sleep, but as surely of elimination and death.

Death always means the irrecoverable cessation of bodily life, but it has many forms—violent, microbic, and natural—each, again, with its subdivisions, and it

cannot be said in any off-hand way that the rate of mortality from every form of death is greatest in Winter. Thus there is an interesting seasonal distribution of disease, of suicide, and even of accidents. Yet the general induction appears safe enough that in northern lands Winter is the time of severest elimination. Thus the season which is apt to seem dull to the field-naturalist is full of interest to the evolutionist. The hedgerows are bare and the woods silent, the pools are clear and apparently devoid of life, the shore is comparatively barren, even the sea has lost certain elements of its wonted abundance. And, though much of this scarcity is only apparent—life lying low, or asleep, or on a journey—we must allow that in many cases life is altogether sped. Proserpina has gone down to Hades. Balder the Beautiful is dead. We have, in short, to recognise the inexorable process of Natural Selection, whereby the relatively less fit to the conditions of their life tend to be eliminated, *i.e.* tend to die before the normal time, and to leave behind them less than the normal number of offspring. Winter is the time when the tree of Life is most rigorously pruned. And this is in many cases well; for, hard as the saying is, the elimination of individuals is one of the conditions in the persistence of a strong race.

In our study of the decadence of Autumn, we spoke of the death of individuals, and of the consolation which is offered in the persistence of the race, but we cannot think long over such matters without recognising that the race itself may perish. We need only reverse the hands of the geological clock a few minutes, as it were, to be convinced of this. We need only go back to the more recent Ice Ages—the ages of Winter's tyranny—which are not long past, as time goes. Indeed, we need not leave human or even modern history at all to find sadly abundant illustrations of lost races.

Keeping, however, to recent animal history, where are the bears who had their dens in Athole, or the wild boars of the great Caledonian forest, or the busy beavers who cut their logs in the Pass of Killiecrankie, or the white bulls who wallowed in the dark waters of the hidden tarns, or the wolves with which Wales paid her tax to King Edgar ?

Or, again, where are the early companions and rivals of our forefathers in Britain—the cave-lion, the cave-bear, the cave-hyæna, the shaggy mammoth and the woolly rhinoceros ? We know them only by their bones in the caves, though it may be that our inheritance still includes some of the hardihood, wisdom, and gentleness which they and others like them helped to work out in man.

Or, going much further back, where are the delicately beautiful graptolites, the quaint trilobites, the giant sea-scorpions, the ancient heavily-armoured fishes, the giant amphibians, the monstrous terrestrial reptiles, the huge sea-serpents or Pythonomorphs, the flying dragons, the toothed birds, the old-fashioned early mammals. The most powerful, the most fertile have not been spared, even those which seem as though they had been built not for years but for eternity, have wholly passed away without leaving any direct descendants to-day. This is no case of leaves falling from off the tree ; it is a lopping of branches.

For some of these lost races, competition was doubtless too keen—they outlived their prosperity and went to the wall ; for others, the force of changing circumstances was too strong—they were not plastic enough to change ; for others, perhaps, over-specialisation or gigantic size or feverish activity was fatal ; for others, it may be that their constitution was in some critical respect at fault, and that they went down to destruction, as Lucretius finely phrased it, " hampered all in their own death-bringing shackles."

However the extinction came about, it was thorough-

going, and these lost races have been blotted out as though they had never been. We cannot console ourselves with any notion that such disappearance is a misnomer for transmutation into some nobler form; that may be true of certain species, which have direct descendants to-day, but it is not true of what we call lost races. Nor is there consolation in the notion that the atoms which were once wrapped up in that whilom bundle of life known as the ichthyosaurus may now be part and parcel of us; for we feel that those particular combinations which we have called lost races—those smiles of creative genius—have gone, gone as utterly as the snow-wreaths of yester year.

Thus from the elimination now observable around us in this wintry season our thoughts naturally pass to the great world-wide process, continuous since life began, which embraces us also in its inexorable sifting. It does not, indeed, explain us, nor the organisms we know, any more than the pruning-hook explains the tree; but given life and growth, we cannot understand our history or that of living creatures apart from elimination. In short, we need our Winter to explain our Summer, and this perhaps is the only consolation which the biologist can suggest to the discontented, that the alternation of Summer and Winter is part of the mechanism which has made the history of the world a progressive development.

THE NATURAL HISTORY OF REST

AN outlook on the animate world in Winter impresses us with the restfulness of living creatures. Seeds are resting in the ground, buds are resting on the boughs, chrysalids are resting in sheltered nooks, the frogs are resting in the mud by the pond-side, the hedgehog is resting amid the woody wreck. Winter in North Temperate countries is a time of rest. Vital activity gradually increases in the Spring months, and reaches its climax in Summer; in Winter we see the down-grade of the curve, which often never re-ascends, but goes lower and lower to the nadir of death.

The physical basis of rest is to be found in the fact of the conservation of energy, for no material system, however wonderful, can create energy. It takes in, it gives out, it transmutes, but it cannot create. Therefore when it expends energy in work, and exhausts its store, it must stop or rest till it gets more. But the matter is complicated by the external rhythms of day and night, of months and tides, of seasons and cycles of years, to which it has been the business of living creatures for millions of years to adjust themselves as harmoniously as possible. Thus we find long periods of expenditure without appreciable income, which are startling from a mechanical point of view.

We are led from many sides to recognise that the living creature is different from any inanimate machine. If it is a machine, it is a self-regulating, self-stoking, self-

adjusting, self-increasing, self-repairing, self-reproducing machine. In fact, in all this it is so marvellous, so ultra-mechanical, that we are sometimes apt to treat it, including ourselves, as if the law of the conservation of energy does not apply. But there is no reason to believe that the student, for instance, who invokes what he calls his "will-power" (a most useful habit within limits) when he ought to go to bed, or who says that he is "too busy to be tired" (usually a short-lived boast), is any exception to the general fact of the conservation of energy, and of its tendency to degradation into that unprofitable mode of motion which we call diffused heat.

We are tempted to make exceptions of ourselves in this restless overworked age, partly because, by traditional dualism, we often think of life too mystically, as if it were a tireless entity. We call upon the resources of the spirit to flog the jaded flesh. But on any theory this is fallacious, except for a temporary spurt. For if the resources of the spirit are reserve powers of the nervous system accumulated in days of rest, such as Sundays, then they are strictly limited. And if they are altogether metakinetic spiritual powers, even then they can only enter into the vital equation by controlling the ordinary corporeal energies, which, by hypothesis, were approaching the limit of exhaustion. Perhaps it is wiser to recognise that to make an *antithesis* of body and soul is a mediævalism. The living organism is a unity.

But we are in a manner right in making a distinction between the inanimate system, where the equation showing income and expenditure is always relatively clear, and the animate system, where the proof of the conservation of energy is a much more difficult matter. We have often kept little water-mites for long periods in glass jars, where the supply of food must be small in the clear water,

and yet whenever we look at these water-mites they are dashing about with headlong velocity, expending energy without apparent exhaustion, continually rushing and hustling, as if they were going to catch a train. That they ever catch anything we do not know. We suppose, indeed, that there is some microscopic food in the water, and that the mites sometimes rest when we are not looking at them, but they have always seemed to us fine instances of what is in some degree true of all living creatures—they have an extraordinary power of accumulating energy, and of accumulating it acceleratively. We know that when we heat a bar of iron, or charge a Leyden jar, or in any other way pass energy into an inanimate system, the transfer becomes more difficult as we proceed; there is more and more tendency to the dissipation of the energy accumulated, and there are effects retardative of further transfer. But, as Prof. Joly points out, it is the opposite with living creatures, and this is their great dynamic peculiarity. They have extraordinary powers of storing energy, and on the strength of their stores they may go on without food or rest for many days. It is a realisation of this power which leads many to deny the claims of rest, and to forget that living on capital has its limits. But although such periods of defiance may be happy and brilliant, it is a perilous habit.

When we contrast the animate and the inanimate after this fashion, there rises in the mind the remarkable fact that the sublimest examples of unrestingness are afforded by the movements of the heavenly bodies, and of the earth itself. For how many millions of years have all these revolutions been going on, without haste, without rest? And what of that mysterious, unceasing movement of our whole solar system towards an unknown goal in space? But the point is, we suppose, that these heavenly

bodies are not, after all, doing very much. Perhaps the mite is more of an agent than they! It is expending more energy relatively to its system, and it is not simply going on in virtue of initial momentum. It is busy. The heavenly bodies that do much in the way of giving off energy, as our sun does, must some day rest. We have only to look up to "yon dead world the moon" to see a world at rest, though it is swept along unceasingly.

Our thoughts also travel readily to the peculiar restlessness of radium. Incessantly, and without appreciable loss, the grain of radium pours forth heat and light. One kind of radium ray is said to consist of little streams of infinitesimally small corpuscles, which travel at the rate of 100,000 miles a second. But after all, the radium grain is being slowly used up; it gives off a something which is being turned into something else; it finds a relative rest in disintegrating.

Let us linger still over the contrast of the lifeless and the living. Throw a ball of potassium on the basin of water, and it rushes about, fizzing and flaring like a thing possessed, but in a minute all its marvellous activity is over, its life as such is sped. But watch, by way of contrast, the similar movements of the little whirligig beetle on the pool; it goes on for a while, like a little water-sprite, darting here, there, and everywhere over the surface, expending much energy. Unlike the potassium pill, however, it does not go out—for a long time at least. When the gong to which it is adapted sounds, it ceases to move, and begins to munch. It re-stokes its engine. When it is tired, or when the external curfew to which it is adapted tolls, it takes a rest. So it persists for weeks and months, and, if it get big rests, it may be for years. In fact, whether they be whirligig beetles or the trees of the forest, living creatures are material systems which have

the power of taking rests. This is part of their essential secret. Conversely, the man who loses the power of taking rest becomes a machine.

We must not, of course, think of the need for taking rests as in any way a new need, which has arisen in a restless age. The need for rest is primitive, and the resting habit has its roots in the remotest past, and its reason in the nature of things.

The argument is obvious and trite. Since all activity, mental as well as bodily, emotional as well as intellectual, involves expenditure of energy, the rate of work must periodically diminish, there must be relative rest, there must be time for the most primitive form of rest which consists in re-stoking the living engine. There are some minute unicellular animals which are said to continue to move about as long as the store of a certain substance within their cell holds out. When that store is exhausted their motor activity is at an end for the time being. Before it begins again, they must accumulate more fuel for the living fire. Here the conditions of rest are seen in their simplest expression. There must be at least a rest for eating—but we do not need to go far to see how much even this is grudged by "the Minister and Interpreter of Nature."

Other needs for rest have gradually arisen. There must be time for the fuel to warm up, for the food to become thoroughly available. But there is much more than this. The activities of daily life, including the stoking itself, involve wear and tear of the vital machinery. There must be rest for repair. In the simplest animals this wear and tear is reduced to a minimum, or the repair is approximately perfect, so that little rest is required. They do not seem even to need to die. In more complex animals, however, the wear and tear is greater as life becomes fuller, the

agencies for repair have a more difficult task, especially as regards hard-worked organs, such as heart and brain, liver and kidneys. Rest becomes more and more imperative. Often the only alternative is death.

Rest is also required when new adjustments have to be made in the body, when there is to be any radical reconstruction, as in the metamorphosis of the grovelling earth-bound caterpillar into the free-flying Psyche or butterfly, or when there has been a relatively trivial change, such as sloughing off an old husk, or when wounds have to be healed. In Hilton's well-known *Rest and Pain* the therapeutic value of rest is demonstrated.

We need not linger over the analogies which the facts suggest for our guidance, and that not merely on the physical but also on the psychical plane. If we are to be kept whole or if we are to be healed, if we need to moult our worn-out armour and present a new front to the world, if we are to reconstruct our system of experience, if we are to have any metamorphosis, the analogy of Nature points to the fact that we must rest. In many cases, as we have seen in a previous study, the larval insect returns in its pupa stage to an almost embryonic simplicity, but the outcome of its rest is its conversion into an emblem of joy and freedom. It is born again.

It is obvious, especially in the animal kingdom, that the need for rest is often bound up with the giving origin to new lives. The queen humble-bee, after its arduous maternal labours, sleeps through the Winter. So the birds that fly southwards, after an exceedingly busy Summer, find a time of relative rest and ease in warmer lands where food is abundant and easily procured.

As we hinted in one of our Spring studies, there seems good sense in what Professor Whitman remarks in connection with the brooding of birds. The supply of heat to

the eggs is "an incidental utility that had nothing to do with the nature and origin of the instinct." To find the real meaning we have to go farther back, and then we see that a recuperative rest naturally follows an exhausting reproductive period. Far below the level of birds, long before there was any incubation, we find animals resting beside their laid eggs or beside their young ones. We grant that this habit also afforded protection, and that it may also be an expression of parental love, but the point is that resting is primitive and incubation derivative.

Even in the plant world we see the contrast between the literal hard work of the vegetative period, when every leaf is a busy laboratory, and the flowering and fruiting period, when the activity is not in getting but in transmuting what has been already gained. And now in Winter we see the leafless trees having, as it were, a deep sleep.

Let us now turn from the general conditions which make rest necessary to the function of the nervous system in this connection. The nervous system is very sensitive to fatigue and to the poisoning of the body with accumulated waste products; one of its many functions is that of warning the body when it is time to rest. But at the same time, as every one knows, the nervous system is extremely sensitive to stimulus; it has in some way great resources within itself; and thus a practical antinomy often comes about. The nervous system is often capable of the treason of urging the body on when the weak flesh would fain rest. On the one hand, it is a rest-index that automatically puts on the brake; on the other hand, it is a spur which incites the tired steed to further effort. The contradictoriness of these two functions is one of the difficulties of a healthy life. Put in another way, the difficulty is that the human resting *instinct* is very slightly developed, and that many find it

troublesome to develop a resting *habit*, which should be formed early if its full utility is to be appreciated.

Furthermore, the difficulty is complicated by our habit of damping down the signals which our rest-index gives us. The extreme signal to rest, as Hilton pointed out, is pain. That is the use of pain. But long before it comes to pain we usually get many signals, which we show no little ingenuity in ignoring. As on the steamers racing on the American rivers, we manipulate the safety-valve so that its whistle indicative of over-pressure may not annoy us. There are many pleasant devices for damping down the rest-signal which our nervous system is almost always ready to give us for our good.

A strenuous American is reported to have said: "I have managed to get a sort of steam-engine into my brain which gives me little rest, and would wear out my body if I did not happen to have the constitution of a buffalo." This is not exactly how a neurologist would express it, but the idea is plain, and the confession indicates one of the dangers of our civilisation,—not of too much thinking, there is little risk of that,—but that one function of the nervous system, which is to prompt to action, to excite, should grow out of all proportion to another function, which is to inhibit, to control, to quiet, to enforce rest. Over-conscientiousness, or rather over-narrow conscientiousness, may lead to what the American called "a sort of steam-engine in the brain, which gives little rest." Unfortunately for the individual, the busy American's "constitution of a buffalo," which enabled him to endure, is not so common as might be desired, partly perhaps because previous generations have taken too little rest.

A Scotch mining engineer, who had spent many years of hard work in Spain, said that half of his toil was in combating the over-restful habit of the Spaniard. As every one

knows, the stage Spaniard will never run if he can walk, never walk if he can sit, never sit if he can lie, and what so much irritated the engineer from a more energetic climate was what he called "the everlasting Mañana, Mañana—To-morrow, To-morrow." But the Spaniard's "Mañana" has its lesson for the American "with a steam-engine in his brain," and that lesson is Rest. The Nemesis of disregarding it is in the ugly word Neurasthenia,—nerve-fatigue, over nerve-fatigue, chronic nerve-fatigue, hereditary nerve-fatigue,—so the dismal story runs till the child is born so tired that it dies.

One of our strongest instincts is the work-instinct, to work at what is natural to us, and it is often too strong for our imperfectly developed rest-instinct, which is almost as important. A narrow conscientiousness which besets too many of us says "Work," and we work long after it can be called day. "We have our work," we say, but we lose Art, and our work becomes toil. Is there not something to be said for the Spaniard's "Mañana," or for the Irishman's advice, "Be aisy; and if you can't be aisy, be as aisy as you can"? This is all the more important since it is obvious that in many respects our organisms have not kept pace with our social evolution.

HIBERNATION

IT is instructive to look over the list of British Mammals and to inquire what solution each offers to the problem of Winter. The migratory birds' solution of evading the hard times altogether is not open to any mammals except bats, and we have few facts regarding their migration. Some of our mammals lay up stores and do not hibernate, *e.g.* the harvest-mouse and the wood-mouse; others lay up stores and also sleep, *e.g.* the field-vole and the squirrel; others neither store nor sleep, but turn white, *e.g.* stoat and mountain hare; others neither store nor turn white, but hibernate, *e.g.* hedgehog, common shrew, and bat; others again do nothing but brave the rigour of the Winter, *e.g.* fox and polecat. The mole occupies a somewhat peculiar position, since it can continue its work and find food below the reach of the frost; moreover, it sometimes makes a store of earthworms which form a staple part of its diet. The water-shrew is another non-hibernator, and we can understand this since the thorough freezing up of rivers or even streams is a rare occurrence. What we see in going over the entire list is, that those which do not hibernate have usually some other marked adaptation to the Winter, such as the habit of storing or of changing colour. In default of anything of this sort and of a callous constitution which can defy storm and scarcity, the animal may save itself by hibernating. It passes into a state when it can starve without feeling it, it lies low with dulled sensitiveness instead of fretting itself to death in a struggle

with the Winter, it keeps in hiding when it is not alert enough to do itself justice, and it gives its body a long rest.

A survey of the Winter-sleepers seems to show that the life-saving reaction must have arisen by the natural selection of variants in the direction of the hibernating habit. That is to say, those that were constitutionally able to assume a comatose condition when the cold weather set in, yet without endangering their lives, were the survivors. On this view we can understand how it is that the hibernating habit is definitely related to the other habits of the creature —for instance, why it should occur in the land-shrew, but not in the water-shrew. It is *an adaptive character.*

But although the hibernating habit may be exhibited by one species of mouse and not by another, being in no way wrapped up with a special kind of constitution, we must recognise that it means in the higher reaches of life a somewhat delicate-adjustment of an ordinary constitution. When a mammal whose constitution is not adjusted to hibernation falls into a cold-coma it is not likely to awaken. This is familiar to us in the case of man and his stock.

Winter Sleep of Cold-Blooded Animals

Many cold-blooded animals, which take on the temperature of the surrounding world, pass into a lethargic state in Autumn. Professor Semper says that they are "lulled to sleep by the falling temperature," but it must be understood that their condition is very different from sleep as we know it. Often it seems more like "Sleep's twin-sister, Death," so thorough is the stoppage of all activity. The common edible snail, *Helix pomatia*, closes the door of its shell with a hard lid of lime and slime, and keeps the door shut for four months. All this time it is fasting; its respiration must be extremely sluggish

through that calcareous wall; its heart, even when the shell is broken, is beating very feebly. This is far below the level which we know in sleep. How much more is that the case with, for instance, the pupæ of butterflies and other insects, in which the whole structure of the larva has been broken down and is in process of slow reconstruction. No doubt all these states are at different levels on an inclined plane, but there is a great contrast between the disorganised pupa, which sinks back sometimes till it is practically a winter-egg that has to be hatched a second time, and the comatose but quite intact snail. There is another great contrast, between the comatose snail and the sleeping dormouse.

Physiology of Hibernation

The physiology of hibernation is still very incomplete, but a few general statements may be ventured :—

1. It is very frequently the case that some store of reserve material exists within the animal which is consumed during the hibernation, serving, for instance, to sustain the animal heat. Thus a store of fat, accumulated when food was abundant, may serve, as it were, to keep the fire " in," though it cannot do much more.

2. A second general statement may be ventured, that hibernating animals show a very marked slackening of all the vital functions. The heart beats feebly and irregularly; the breathing movements are " shallow and infrequent, sometimes coming practically to a standstill " ; there is no excretion from the kidneys, or next to none; the usual muscular reflexes are weak, and the senses are not readily stimulated. In short, the whole metabolism of the creature is at a very low ebb.

3. Very significant is the fact that in hibernating

mammals there seems to be a suspension of the normal "warm-bloodedness," or the power of retaining an almost constant body-temperature. To appreciate this, a short digression is necessary. The animal heat of the body is mainly due to the chemical processes involved in the contraction and life (apart from contraction) of muscle, the secretion of glands, the oxidations in the blood, and even in the work of the brain. There is necessarily a similar production of heat in the cold-blooded animals, but they have no physiological adjustment for conserving what they produce. They are thus dependent on the temperature of the surrounding medium, towards which they always approximate. In warm-blooded animals, however, there is a somewhat intricate nervous mechanism which adjusts income and expenditure of heat, regulating both the heat-production and the heat-loss. The passive muscles, for instance, can be incited if need be to *produce* more heat; or, on the other hand, a dilation of blood-vessels and a flow of sweat may cause the animal to *lose* more heat. And this automatic regulation is so smooth in its working that the body-temperature of birds and of mammals remains constant, year in year out, except in peculiar cases, such as the fledgling in the deserted nest which has not got its thermotaxic mechanism established, or the fevering animal in which the mechanism goes out of gear, or the birds among the snow which have their regulating mechanism worn out by the hopeless attempt to respond to the prolonged exposure, or, lastly, the hibernating mammals.

In the hibernating mammal, what happens is, that as the outer world gets colder and colder, the heat-regulating mechanism ceases to act, and the creature is saved from the collapse consequent on a certain defeat, by becoming temporarily cold-blooded (or poikilothermal). Its

temperature ceases to be constant, and follows the fluctuations in the external world. Meanwhile the creature sleeps. Should the external temperature fall too far, the sleeper may never awaken, or it may waken suddenly and make violent efforts to get warm before it dies.

Horvath made the interesting and important observation that a zizel, *Spermophilus citillus*, lying in its winter sleep, always has nearly the same temperature as the surrounding air. "In one case the temperature of the room was 2° C. above zero, and a thermometer inserted in the rectum marked exactly the same degree; in another experiment the animal was sleeping in a room at about 9° to 10° for several days, and its body (in the rectum) was at 8·4°. This shows that during their Winter sleep warm-blooded animals become truly cold-blooded; at any rate this is true of the zizel, since its temperature corresponds with that of the surrounding atmosphere." [1]

4. In his remarkable work on *The Natural Conditions of Existence as they affect Animal Life* (1881), Professor Karl Semper called attention to the value of Horvath's studies on hibernating mammals, referring to two in particular: "It is usually supposed that the awakening of winter-sleepers is occasioned by a rising temperature; but in Horvath's investigations this was never the case; during two hours and forty-five minutes, which, in the one experiment communicated, were needed for complete awakening, the temperature of the room remained exactly the same—10° C.—as during the three previous days when the animal was still asleep. *This proves that the waking up must be caused by some internal cause which we do not yet know.*"

"But his other observation is far more remarkable; namely, that during the awakening, the body-temperature

[1] Semper's *Animal Life*, p. 112.

rises rapidly, and much more rapidly during the second half of the process than at the beginning; for instance, in the experiment which is given in detail it rose in the first hour and forty-five minutes only about 6·6° C., and in the following fifty minutes about 17°. This remarkably rapid increase of body-heat took place, moreover, without any vigorous movements, which might otherwise have been supposed to cause it—even the rapidity of breathing showed no increase corresponding to the rise of temperature."

In relation to our general thesis that "Life is rhythmic, and that it is punctuated by the seasons and other external periodicities," Horvath's results are of much interest. Much more requires to be done, but they seem to suggest that an internal periodicity has been definitely established, which now runs its course with some degree of autonomy, apart from external stimuli. The sleeper *may awaken* constitutionally, whether the Spring be warm or cold, just as a man may awaken after his usual amount of sleep whether the morning be light or dark. But more facts are required.

It may be, as Semper pointed out, that the problem is complicated by the nutritive condition of the hibernator. Thus Dr. August Forel, famous for his studies on ants, believed that influences determined by food were more important than those of temperature. "A dormouse that he kept went to sleep even at a high temperature of the air, in August and September, and slept as soundly as in a true winter sleep, while its body temperature was never more than a few degrees higher than the air."

There is much that is obscure in the physiology of hibernation, but several general facts stand out clearly. It is a very effective life-saving expedient,—an abandonment of the struggle to make ends meet, a banking up

of the fires of life so that there is extremely slow combustion,—and it works well as long as the external temperature does not fall below $+1°$ C. It is probably also very useful in giving the organs and tissues of the body a long rest—a rest even from eating. It represents an interesting reminiscence of a more primitive physiological state when the temperature-regulating mechanism was not yet well established in the ancestral mammals. Of this primitive condition we have a permanent illustration in the Monotremes, which are imperfectly warm-blooded. Thus the temperature of the Spiny Ant-eater (*Echidna*) varies with that of its surroundings through the extraordinary range of 10° C.—a fine instance of a physiological connecting link between cold-blooded and warm-blooded. And that is just what every hibernating mammal also illustrates.

THE WHITE WINTER COAT

A FAMILIAR human reaction to the conditions of life in winter is a change of dress. We clothe ourselves in the skins of other mammals, putting on layer after layer of wool, and, it may be, a fur coat on the top. Similarly it is known of many mammals that they grow a thicker and longer coat of hair as the days become colder. But what concerns us now is the change of colour to white, as we see it, for instance, in the mountain hare, among mammals, and in the ptarmigan, among birds. How does this change come about, and what is its significance ?

In the first place, as to the occurrence of this peculiarity of changing to white in winter, it is exhibited by distinctively Northern creatures—the Arctic fox (*Canis lagopus*), the Hudson's Bay lemming (*Cuniculus torquatus*), the ermine (*Mustela erminea*), the mountain hare (*Lepus variabilis*), the American hare (*Lepus americanus*), and the ptarmigan (*Lagopus albus*). This is interesting, since permanent whiteness is characteristic of many Northern animals, such as Polar bear and American Polar hare, Greenland falcon, and snowy owl. It is probable, therefore, that changing to white is advantageous for the same reasons as permanent whiteness.

It is also instructive to notice that some of the mammals that usually turn white do not always change, and that this is connected with the habitat. Thus the Arctic fox (*Canis lagopus*) does not usually turn white in Iceland ; the mountain hare rarely changes in Ireland ; and white stoats

or ermines are comparatively rare in England. The inference is that the changes which bring about the whiteness require *at least the stimulus* of a considerable degree of cold. It does not by any means follow that the cold is the direct or mechanical cause of the whiteness.

To the question, What actually takes place when the white dress is put on, a fairly secure answer can be given in some cases. But in other cases we have not as yet sufficient data. It is well known that the stoat or ermine (*Mustela erminea*), which is brownish-red in summer, usually becomes a beautiful white in winter, all but the black tip of the tail. How is this effected ? The older naturalists, such as Bell, who wrote on British Mammals, believed that the brownish-red hairs lost their pigment and became white, which is not in any way improbable. But Professor William MacGillivray was one of the first to doubt the accuracy of this view, pointing, for instance, to a specimen caught in December, which showed a *mixture* of white and brownish-red hairs. " The hairs of the latter colour were not in the least degree faded, and those of the former were much shorter, and evidently just shooting ; so that the change from brown to white would seem to take place by *the substitution of new white hairs for those of the summer dress.*" This view has been confirmed by the very careful investigations of Professor G. Schwalbe.

Several instances of stoats of a brown colour patched with white, in which the white hairs were of the same length as the brown, led MacGillivray to think that " sometimes the brown hairs themselves, on the application of intense cold, become whitened " ; and of this as an exceptional occurrence there is some modern corroboration. For in the case of the mountain hare, in which, according to MacGillivray, the white winter hairs are due to fresh growth, the investigation of von Loewis leads to the conclusion that brown hairs may sometimes be changed, *in situ*, into white ones.

PTARMIGAN AND MOUNTAIN HARE

(XI)

In a famous experiment made by Sir John Ross, a Hudson's Bay lemming was kept in the cabin of the ship through the winter and did not change colour. But on the first of February it was exposed on deck and it had several white patches next day. It turned white in a week, and died a few days afterwards. In this case the blanching must have been due to a change in individual hairs, such as sometimes occurs very rapidly in man as the result of a nervous shock. It is probable, as Mr. F. E. Beddard points out in his interesting book on *Animal Coloration* (1892), that the suddenness of the change robbed the experiment of part of its value in proving that the cold is the stimulus that induces the blanching. "The cold was administered in a sudden dose, which may have produced an effect analogous to a nervous shock."

In the case of the American hare, the investigations of Welch (*Proc. Zool. Soc.*, 1869) seem to show that the process of assuming the white colour is twofold. On the one hand, there is a new growth of white hair; on the other hand, there is a slow blanching of coloured hairs.

The whiteness of hair or feathers is due negatively to the absence of the usual pigment, and positively to the presence of minute gas bubbles in the cells. A new white hair or feather is not in any special way difficult to understand, it simply implies some slight change in the chemical processes involved in all development. The pigment is not formed or not completely formed, and gas vacuoles are abundant in the cells. It seems, sometimes, as if the raw material (or chromogen) of the pigment were present, but the magic touch of the ferment required to make this a coloured stuff is absent.

When a hair already coloured becomes white very suddenly, there seems to be a rapid change in the pigment material, which ceases to be coloured. It is well known

that a very slight change of alkalinity or acidity will change the colour of a flower, and that boiling water makes the blue lobster red. But when a hair or feather becomes white slowly, the change may be of a quite different kind. For Metchnikoff has shown that the wandering amœboid cells—the phagocytes—of the body, which discharge so many useful offices, pass into the hair and down again, carrying a microscopic burden of pigment material. Whether the change be quick or slow, there is an associated physical change in the accumulation of gas vacuoles. For the whiteness of grey hair is like the whiteness of foam.

When we remember that albinos often crop up as the result of inborn variations in all sorts of animals, even the blackest of them ; that albinism occurs in all possible degrees of thoroughness ; that mammals periodically moult their hair and birds their feathers,—there seems no particular difficulty in understanding how species may have arisen with the constitutional idiosyncrasy of assuming a white dress in winter, provided always that the change can be shown to be distinctly advantageous.

There appear to be various advantages in a white dress in very cold snowy regions. For a hot-blooded animal, with a temperature high above that of the surrounding world, the loss of heat is less with white hairs or white feathers than with any other colour of dress. It is physiologically the most comfortable dress, putting least strain on the complex mechanism that regulates the body-temperature in warm-blooded animals. This is probably the chief advantage of turning white in winter, but it must also be admitted that a white dress is the least conspicuous in snowy regions as well as the most comfortable.

Where the struggle for existence is keen, it may be but a little thing that turns the balance towards survival or elimination. Professor Davenport had 300 chickens in

a field, 80 per cent. white or black and conspicuous, 20 per cent. spotted and inconspicuous. In a short time twenty-four were killed by crows, but only one of the killed was spotted. In this case the quality of whiteness was disadvantageous, but in the North or among the mountains those animals who turn white in winter are likely to have their chances of life improved. This, at least, is an outline of the selectionist interpretation of the origin and significance of the white winter dress.

No better example of a victorious creature could be given than the snowy owl (*Nyctea scandica*), a native of the barren grounds of the "Far North," that sometimes visits us in very cold winters. It is a big bird, about two feet in length, of white plumage with variable dark spots and bars; it has a strong and easy flight, and hunts by day, picking up snow-birds like the ptarmigan, snow-mammals like the Alpine hare, besides lemming and mice, and even fishes. It has a wide distribution and a successful life; it seems indifferent to storms, except in so far as they destroy its food; it is wary but fearless, and a pair of them will attack a man who comes near the nest among the reindeer moss. The male is said to feed the mother and her large brood. The harmony between the plumage and the snowflakes is but one expression of the successful balance that this great bird has struck between the insurgent claims of an imperious nature and the insouciance of a merciless physical environment of the very hardest type. "The cry, seldom heard, is wild and wailing," but it is a cry of victory, for the bird has solved its problem and is master of its fate. There seems a dim consciousness of this in its fierce eyes.

THE SQUIRREL'S STORE

THE storing instinct is shown by diverse kinds of animals at different levels of organisation. It must have been evolved over and over again independently. We think at once of ants, harvest-mice, beavers, even moles—a few of the animals that store as the squirrel does. Perhaps it is just a step or two in advance of the not uncommon habit of hiding or burying surplus food, but we can readily understand how important it is in countries where there is scarcity of food in Winter, and for animals whose food keeps well, and which do not hibernate.

Storing is an autumnal industry on the squirrel's part. Hazel-nuts, beech-nuts, and acorns are hidden in many separate hoards, for the wisdom of not putting all the eggs into one basket has been realised in practice at least. It is interesting to notice that the young squirrels, which are born about May, remain at home for a year, which is perhaps another reason for storing.

It is difficult to say what a squirrel will not eat,—from fruits to the eggs and young of wood-pigeons, from fir-cones to sappy shoots,—but its characteristic food is the hazel-nut. Holding the nut in its paws, the squirrel cuts a circle so that the shell falls into two parts, often halves, and it peels off all the brown skin before it begins to bite. Gilbert White pointed out long ago that " there are three creatures, the squirrel, the field-mouse, and the bird called the nut-hatch, which live much on hazel-nuts ; and yet they open them each in a different way. The first, after rasping off

the small end, splits the shell in two with his long fore-teeth, as a man does with his knife; the second nibbles a hole with his teeth, so regular as if drilled with a wimble, and yet so small that one would wonder how the kernel can be extracted through it; while the last picks an irregular ragged hole with his bill; but as this artist has no paws to hold the nut firm while he pierces it, like an adroit workman, he fixes it, as it were, in a vice, in some cleft of a tree, or in some crevice, when, standing over it, he perforates the stubborn shell."

Those who have kept squirrels are in general agreement as to their considerable attainments in the way of intelligence. But we are probably mistaken if we credit them with any forethought of the Winter. It is more likely that the storing is instinctive. This is not contradicted by the fact that in mild parts of the country squirrels sometimes omit to store. For it is well known that instinctive activities often require particular stimuli to pull the trigger which leads to their expression.

Another point of interest lies in the fact that the squirrel is not much of a winter-sleeper. This makes the need for storing more obvious. In very cold districts and severe Winters the squirrel sleeps a good deal, but it usually lies up only for a day or two at a time, and sometimes it does not slumber at all. Thus in the storing device we see simply one of the many ways of escaping from the grip of Winter. Most of the birds fly away, the mountain hare turns white as snow, the bats fall into deep sleep, most plants pass into a resting stage, and so on—many other creatures follow the squirrel's adaptation and lay up stores for the evil days.

JETSAM

IN spite of many disappointments, there is always a mild excitement in a walk along the shore—especially after a storm. One never knows what one may discover among the jetsam—the rubbish, as some people would say. But this is to miscall the jetsam, for although there is sometimes an element of rubbish—the débris of civilisation—the uninviting word is seldom appropriate in reference to the whole. What we mostly find is *the wreckage of life*—creatures that have been torn from their moorings, or that have been forced by currents into the grip of the incoming tide, or that have been battered to death and then swept ashore. The jetsam differs greatly at different seasons and in different localities, but it may be of interest to take a representative sample.

The sand is sometimes mixed with dead or dying Foraminifera (chalk-forming unicellular animals), such as the beautiful *Polystomella,* which is like a microscopic miniature of a Nautilus shell—an instance of that convergence of architecture which we often find among unrelated forms at very different levels in the animal kingdom. This *Polystomella,* which we can sometimes see as a white speck on the freshly dislodged seaweed, is a good illustration of the *relative* nature of simplicity. It is a single cell,—a unit of living matter,—but it is structurally very complex in comparison with a drop of white of egg. It has a spiral chambered shell; it occurs in two different types (like males and females, though that does not seem to be the

meaning of the dimorphism), and it has an intricate life-history.

Much higher in the scale of being are the sponges, such as "Mermaids' Gloves," "Elephant Ears," "Crumb of Bread," and the like, to give them their quaint but not inappropriate popular names. They have been wrenched away from their anchorage and tossed up on the beach. We cannot look at them with irreverence, for the sponges were the first animals to be successful in having a "body"; and, though they have no organs, they illustrate tissues in the making. We try a piece against our skin, and discover in its rasping effect why even large British forms are of no use for toilet purposes. From a zoological point of view, it is profitable to scrutinise a big sponge carefully, for there are sometimes interesting creatures in its recesses. A sponge is often a living thicket, in which small animals play hide-and-seek.

Even more plant-like than the sponges are the zoophytes, which we find so abundantly among the piled-up seaweed or growing on it—colonies of polyps protected within a firm tubular investment, often aborescent in their mode of growth, and always fascinatingly beautiful. There is something suggestive in the technical names of the great types—Tubularians, Campanularians, Sertularians, and Plumularians, or in the popular names like "sea-fir." Very plant-like, indeed, most of them appear; but that is again only a superficial resemblance of "convergence," as observation of the living creatures makes plain, for they have mouths and food-canals, waving tentacles and stinging lassos, and many of them bud off swimming-bells or medusoids, which swim in the Summer seas like miniature jelly-fishes.

Sometimes the whole of the flat beach is thickly strewn with true jelly-fishes—a distinctive element in the Summer

jetsam. They consist in large proportion of "animated sea-water," and it is instructive to watch them in all stages of evaporation till only a thin transparent disc is left on the sand. One remembers the striking fact that quite a number of extinct genera have been described from their exact impress on fine-grained rocks. Jelly-fishes are obviously open-sea animals, and their abundant occurrence on the shore illustrates wastage. They have lost their bearings or got into the grip of inshore currents.

Sometimes tossed up together are two creatures which are almost violently contrasted, though, as a matter of fact, they are not very distantly related, namely, Dead Men's Finger (*Alcyonium*), a flabby, fleshy colony with no pretence to elegance, and the Sea-Pen (*Pennatula*), a graceful plumose colony with a central axis and the polyps arranged on pinnules up each side, like the barbs of a feather.

There is sometimes a whole bank of the flexible tubes of *Lanice conchilega*, a worm that binds shell fragments and sand-particles together, literally "making ropes of sand," and there is never difficulty in finding calcareous worm-tubes, like those of *Spirorbis*, attached to the seaweed, or those of *Serpula* on shells and stones. Now and again among the seaweed we find the sea-mouse, *Aphrodite*, like an entangled fragment of a rainbow, so iridescent is it.

Piled up in great quantities often are the fronds of the sea-mat (*Flustra*), leaf-like or seaweed-like till the eye catches the innumerable small holes tenanted by the animals forming the colony. The biologist handles it with some affection, for was it not the subject of Darwin's first scientific paper? And those who enjoy "beauty-feasts" cannot do better than give some time to the numerous calcareous relatives of the sea-mat which form exquisite growths on shells and stones. In illustration of contrast between two types not very distantly related,

we may compare the gelatinous translucent *Alcyonidium gelatinosum* and the lace-like *Membranipora membranacea* spreading like a film on the large fronds of seaweed.

Among the transient components of the jetsam are the delicate shells of the heart-urchin (*Echinocardium*), which we find with all the spines rubbed off and beautifully white. The tread of a black-backed gull's foot is enough to break them, and they soon pass into the common denominator of the sand. The purple heart-urchin (*Spatangus*) is hardly less brittle. It is interesting to find the strong common sea-urchin (*Echinus*), with all its spines worn off and the balls where their sockets fit on to the shell polished smooth. The masticating mill or lantern which Aristotle saw more than two thousand years ago has fallen out and lies by itself on the sand—a puzzling structure to those who do not know what it is, and equally puzzling to those who, knowing what it is, inquire how it came to be. Allied to the sea-urchins are the starfishes, which are often well represented in the jetsam, sometimes occurring in the so-called "comet form"—one arm in process of budding off the missing five. For the regenerative capacity of these creatures is extraordinarily great — a missing arm can be regrown and a surviving arm can regrow all the rest.

As we search among the jetsam, crowds of "sand-hoppers" spring high into the air, light again on the sand, and are gone. Many of them are so like the sand in colour that it is difficult to see them till they move, and then they burrow with great rapidity. Some of them "feign death," as we say in our ignorance, when they are touched, and will lie absolutely motionless for many minutes. Suddenly the machinery begins to move again, they spring into the air, and we see no more of them. These shore-amphipods are interesting in many ways, but we cannot do more than refer to the important part they play in

the littoral economy by cleaning things up. They devour everything that is edible in the dead bodies of animals, both large and small, and make beautifully clean skeletons, just as the ants do in the meadow. Along with these genuine inhabitants of the shore there are representatives of the same crustacean class in the jetsam. In the early Summer especially we find many moults—from the glassy husks of acorn-shells or barnacles to the substantial cast shell of the edible crab.

On many beaches the most conspicuous component of the jetsam is that furnished by molluscs, whose shells afford an unstinted "beauty-feast." In shape and colour they are singularly attractive, and they are full of unsolved problems. Even to the simplest question, What is the chemistry of their formation ? we can give no answer, though there are reasons for suspecting that shell-making is an organised way of using up waste-products.

In the regular lines patent on the surface of the shell, and often accentuated by fine gradations of colour, we have a fine instance of the periodicity of growth, and doubtless also, if we knew enough, of punctuation from without.

To get a good instance of the correlation of habit and structure, we have only to lift a dog-whelk's shell and contrast it with a periwinkle's. The former has a notch at the mouth of the shell, in which, during life, there lies a breathing-tube (or respiratory siphon); the former has no notch and no siphon. And the interesting point is, that those with the notch are almost invariably carnivorous and those without the notch are vegetarian.

Many of the bivalves, such as the very common *Venus gallina*, show a neatly bored hole up near the hinge, and this explains their presence in the jetsam ! The hole was bored by a carnivorous gastropod, which killed the bivalve

and devoured its body, leaving the empty shell to be tossed up on the sand.

There are many curious items in the molluscan jetsam. These chaffy balls that the wind blows along the sand are the empty egg-capsules of the giant whelk or "roaring buckie"—cradles which were the scene of a grim struggle for existence between the first hatched larvæ and those that emerge later. These translucent "sea-pens" of chitin and these "sepiostaires" of spongy lime which are collected for cage-birds to peck at, are both the vestiges of the vanished shells of squid and sepia. Sometimes a whole fleet of cuttle-fishes gets into the grip of the tide and is stranded on the flat beach, where they writhe their arms impotently till the gulls give them their release.

Backboned animals do not contribute much to the jetsam, but here and there we find a stranded fish, a bird that has been killed, or a porpoise that has run aground. Not very uncommon in some places is the body of an angler or fishing-frog. This interesting fish often half buries itself in the sand in relatively shallow water, and the lure that dangles from the end of a long dorsal fin-ray seems to attract little fishes to their destruction. A fresh specimen that has come too near the shore will afford an unforgettable instance of adaptation, for the numerous teeth on the jaws that border the enormous gape are hinged at their base, bending inwards at the least touch, so that entrance to the mouth is as easy as exit is difficult.

A distinctive "common object of the seashore" is the four-cornered "mermaid's purse," with each corner drawn out into a tendril. It is the egg-case of a skate or of a dogfish; it is made of keratin or horn, just as our finger-nails are; its tendrils twine automatically around seaweed, so that the laid egg is saved from being smothered in the mud, and is rocked by the waves till the embryo is ready to be

hatched. Then a chemical change in the white of egg dissolves the horny shell along a line of weakness at one end, and the young fish emerges. Those mermaids' purses thrown up on the shore are usually *emptied* egg-shells, as the opening at one end shows.

The birds among the jetsam are often of great interest—even of biological interest. Thus the large number of young guillemots and razorbills in Summer suggests the mortality incident on the first plunge from the rocks. It is the first step that costs, but in some cases the natural mortality is artificially exaggerated by salmon-nets, in which many marine birds get entangled and drowned. It is interesting in another connection to find the stranded-bodies of puffins in the winter-time, when there is not a puffin to be seen on any part of the coast for hundreds of miles. These bodies have been washed in from the open sea, where many of our Northern puffins seem to spend the winter months. And he must be dull indeed who experiences no thrill in finding among the seaweed on a winter day a rarity like the wedge-tail petrel, a distinctively pelagic bird, killed perhaps by flying against a ship, and probably washed in from a great distance out to sea.

What a variety of biological impressions we gain from this walk among the shore-jetsam. There is sometimes an overmastering impression of the abundance of life. When we see the stranded fleet of jelly-fishes, scores of squids in one small bay, zoophytes to fill a sack with, a litter of sea-mats, hundreds of fragile heart-urchins, and so forth, we return to the old image that life is a stream that is always overflowing its banks.

Nor can we walk along the shore looking at the jetsam without being impressed with the variety of different kinds, as well as with the uncountable number of individuals. Even if we do nothing but gather shells (on a good shore for

A SHORE-POOL: SEA ANEMONES AND HERMIT-CRAB

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them) we feel that we are in the presence of an overflowing form-fountain, prodigal multiplicity, endless resources.

> "But what an endlesse worke have I on hand
> To count the sea's abundant progeny,
> Whose fruitful seede farre passeth those on land,
> And also those which wonne in th' azure sky.
> How much more eath to tell the starres on hy,
> Albe they endlesse seem in estimation,
> Than to recount the sea's posterity,
> So fertile be the floods in generation,
> So huge their numbers and so numberlesse their nation."

Another impression is of the wastage of life—in regard to which the physical forces are quite careless. There is absolute insouciance in Nature. The beach is strewn with jetsam as thickly as the woodland with withered leaves, but it is a jetsam largely made up of corpses. There are, indeed, empty shells tossed up, and the moults of crabs and various items of this sort, but the great bulk of the jetsam consists of corpses.

In contemplating the jetsam we see one aspect of the struggle for existence, the non-competitive aspect—the struggle between organisms and their physical environment, between life and fate. What is thrown up on the shore between tide-marks is only a small part of what is continually being dislodged by storms, and there can be no doubt that there is a ceaseless thinning. It may be that this sometimes leaves appreciably more room for those creatures which are not thinned, and it may be that within the members of a species those that vary in the direction of resisting dislodgment survive in appreciably greater numbers. But we have no data. It seems likely, indeed, that in many cases there is no Natural Selection at all, for that is a much narrower category than the Struggle for Existence. From the absence of uniformity in the jetsam in a tract of shore which we have studied for many years we have a general impression that much of the elimination

is quite indiscriminate, and therefore without direct importance in evolution. It is very important to understand clearly that the only eliminative processes that can be regarded as counting for much in evolution are those which are *discriminate and consistent.*

Another consideration of some interest is brought home to us when we watch the jetsam being covered up by the sand either borne in by the tide or blown by the wind. We see how the first step towards fossilisation might be taken when some change in currents piles up a heavy sandbank near the high-tide mark, burying a sample of the jetsam. But even if the sample was a good one, and if all should be preserved in a future sandstone, the result would be far from a fit representation of the local fauna of our times. It would be almost as misleading to judge of the civilisation of the early twentieth century by the débris washed up on the beach near a large town. Nor should one fail to notice that even if a whole stretch of jetsam were quickly buried, many items would have no chance of being preserved or of being well preserved, for the Amphipods and Bacteria and other scavengering creatures have already begun their destructive work. The sea's memoranda are apt to pass quickly beyond all hope of deciphering.

We cannot watch the jetsam through several consecutive days without getting vivid illustrations of the circulation of matter. The squid is scarcely dead before the gulls are pecking at it, and even land birds like rooks come down to the feast. The Amphipods already referred to are continually doing with their microscopic nibbling what birds do when they pick a dead fish clean. We lift up the substantial shell of an oyster or of a "roaring buckie" and find it riddled with holes, neatly bored as if with a gimlet,—the work of a boring sponge Cliona, which thus helps the shell a long way towards its incorporation with the sand. It is an

interesting occupation for a leisure hour to sit with a lens in hand sifting the sand—distinguishing here a fragment of shell and there a piece of a sea-urchin's spine, here a remnant of an acorn-shell's rampart and there a Foraminifer. One can arrange a series of grades of fineness, like different samples of sugar ; they are stages in the process of reduction towards that lowest common denominator which we call the sand of the seashore.

OLD AGE AND DEATH

ALL around us, if we will, we may see living creatures growing from the apparent simplicity of germs to the obvious complexity of adult organisation. But from their earliest hours they are singled and sifted. Out of a million oyster-embryos energetically swimming in the sea, it may be that only one reaches maturity, and even then it may be that it has only survived to become what Huxley playfully called "a gustatory flash of summer lightning." In all ordinary cases, however, throughout the animal kingdom there is abundant survival, and those who escape the dangers of the first part of the Mirza bridge form a strong contingent. As we watch them we see that they wax stronger, attain a stable constitution, adjust themselves masterfully to their environment, and give rise to others like themselves. From almost every point of view the curve of their life rises, and they are full of promise. We see life victorious and triumphant.

But as we continue to watch, we begin sooner or later to detect a rift within the lute. We begin to detect symptoms of decadence. Vigour slackens, the range of activities narrows, the thrusts of adverse circumstances or of intrusive disease are less successfully parried, the organisms drift instead of swimming in the environmental current, they lose their grip on their surroundings which seem to close in upon them, they sometimes show internal symptoms of weakening and atrophy—in a word, they *grow old.*

Our problem is to try to understand more clearly why it is that the curve of life, after attaining what the thoughtful biologist Treviranus called a *vita maxima*, should begin to droop, sinking quickly or very slowly to a nadir of *vita minima*, at the threshold of death. Why do living creatures grow old, or, to be more accurate, why do many living creatures grow old?

As this is a very difficult problem—not admitting as yet of complete solution—we must work round about it, instead of venturing on a direct attack. By patiently approaching it from different sides, we may reach in the end some greater clearness. Shakespeare had the problem before him when he wrote: "And so, from hour to hour, we ripe and ripe, And then, from hour to hour, we rot and rot, And thereby hangs a tale." But the tale is not as yet coherent.

One of the interesting results of modern Biology is expressed in the somewhat startling phrase, which we owe to Professor Weismann—*the immortality of the Protozoa*. This implies that the simplest animals (and plants too for that matter)—the unicellular organisms—are not subject to *natural* death in the same degree as higher forms are. It seems that many of them, at least, are practically immortal. They may be devoured, they may be crushed, they may be killed in a hundred ways; some are liable to fatal infection from microbes; but of their natural death there is no definite proof.

In the open sea there are countless millions of unicellular organisms—both plants and animals—Foraminifera, Radiolaria, Diatoms, Desmids, and so forth—which are continually being killed by vicissitudes of temperature and the like. Dying, they sink slowly down, like a ceaseless, gentle snow-shower, it may be through miles of water, to form no inconsiderable part of the food-supply of the

animals who people that dark, cold, silent, eternally calm world which we call abyssal. But so far as we know, these sinking atomies have all been *killed* ; they are subject to violent or environmental death, but not to natural death.

It may be noted, in passing, that many of the Protozoa are but little troubled by bacterial or microbic infection, which is so fatal to higher forms. Metchnikoff has shown that Amœbæ, for instance, are able to engulf and digest various kinds of very virulent microbes, just as the wandering amœboid cells or phagocytes of higher animals (and our own indispensable bodyguard) are able to do. To certain minute parasites, however, even the Amœbæ succumb.

How is it, then, that these simple pioneer organisms escape natural death ? The presumably true answer is twofold : that being relatively very simple,—in a sense without a body,—they are able to sustain with persistent success the vital equation between waste and repair ; and that their common mode of multiplying (by dividing into two or more units) is inexpensive and not attended with any loss of life. On the one hand, we reach the idea that death was " the price paid for a body " ; on the other hand, we see that in the simplest forms of life immortality has not yet been pawned for love.

In many living creatures the giving origin to new lives is the beginning of death. The annual plant dies as its seeds are scattered. Many a worm, many an insect, never survives the climax in which it gives origin to others like itself. " Quasi cursores lampada tradunt," and as the torch is handed on to another, the runner falls and dies. Even among backboned animals, cases are known, *e.g.* of lampreys and eels, in which the parents collapse and die after reproduction. The little fish *Aphia pellucida* is like an annual among plants, it lasts only for a year. Repro-

duction is exhausting and often fatal. But this does not apply to the Protozoa.

Among unicellular organisms the process of multiplication is simple and inexpensive, and correspondingly rapid. One becomes two by dividing, and we cannot speak of death when there is nothing left to bury. A little one soon becomes a thousand. From one Infusorian there may be a million in four days.

It seems, however, that there is, in some cases at least, a limit to the number of successive divisions that can occur in an isolated family of Infusorians all descended from one, and in the absence of that pairing of unrelated forms which normally occurs in natural conditions. After a certain number of generations—which can be extended by using stimulants, such as strychnin—senile decay sets in, the new members are born old, they are dwarfish and degenerate; soon they cease to be able to feed or divide. Even at this low level of organisation it is only through the fire of love that the phœnix of the species can renew its youth. Without conjugation of unrelated forms the family comes to an end.

Now it may be that this limitation to the number of successive cell-divisions has a deep significance in regard to the growth of higher animals, which is, of course, accomplished by successive cell-divisions. Here, too, there are limits to multiplication and renewal. In brains, notably, the cells stop dividing or multiplying at a very early date—it may be before birth! Thus we see the force of Professor Weismann's sentence: "The real cause of death is to be looked for, not in the using up of the body-cells, but rather in the limits to the reproductive power of cells."

What has been said throws light upon the problem of senescence in the higher forms of life. It is to be regarded not simply as an intrinsic necessity; it is incident

on the complexity of the bodily machinery, on the accumulation of arrears in the process of repair, on the limits which are set to the multiplication or renewal of cells, and also on the occurrence of organically expensive modes of reproduction.

The general idea is that the wear and tear is not quite counteracted by food and rest. The recuperation is often incomplete, and there is an accumulation of physiological arrears. The organism gets quickly or slowly into debt. The items may be infinitesimal, and in many animals a violent death comes before their accumulation begins to tell. In other cases they mount up and lead to that physiological insolvency which we call senescence and death.

The case of the worker hive-bee illumines the whole subject. In our childhood many of us—who are constitutionally fond of laziness—used to be urged to consider "the little busy bee" which "improves each shining hour," but a more intimate and critical knowledge of bees and their behaviour has entirely shaken our confidence in this exemplar of our childhood. Let us lift only one corner of the seamy side, by asking how the shining hour improves the busy bee. When we ask this question we find that the worker hive-bee grows old with extraordinary rapidity, and often dies a few weeks after its industry begins. It grows old while it is still young, a victim to over-exertion. With all its getting, it gets not wisdom, but foolishness, for its brain-cells go steadily and surely out of gear. A large number pass into a state of irrecoverable fatigue-collapse. As Professor Hodge says: "The nerve-cells, in the course of the bee's daily work, gradually cease to be functional, and die off, until no more are left than are sufficient for the necessary vital functions." Thus the premature growing old of the bee is a warning against over-industry.

We have sketched what may be called the general

wear-and-tear theory of senescence, but many more detailed suggestions have been brought forward. From a large series of measurements, on the growth of guinea-pigs in particular, Professor C. S. Minot of Harvard reached the conclusion that the rate of increase in weight (measured in percentage of total weight) steadily falls from the earliest days after birth. Whereas the first ten per cent. of addition in weight is made in about two days, the twenty-fifth addition of ten per cent. (absolutely much greater) requires nearly eighty-eight days. In fact, growth illustrates the law of diminishing return. It is an uphill business all the time, but the hill gets steeper and steeper as we go up, until at length the gradient becomes impracticable and growth stops.

Minot compares the business of growing to the building of a wall by one man: "The wall is built and grows larger, develops, but the man grows more and more tired, and as he grows more fatigued, and as the wall becomes higher, the progress thereon becomes slower and slower, but the wall has developed all the time. So we see that the body develops all the time, but the power to continue the development of the body steadily diminishes." Professor Minot maintains that the law holds true of man, of chickens, of rabbits, of dogs, of ferrets, and of some other animals.

We cannot follow Professor Minot when he goes on to say that there is from earliest youth onwards "a gradual loss of vitality." We do not know—no one knows—what vitality precisely means, but it surely means more than the rate of growth in weight. It may be that in some domesticated animals, such as sheep, cattle, and poultry, there is a decrease in the range of vital activities and interests after adolescence is past, and it may be that the two-year-old child lives a more strenuous day than a man of sixty; but these are exceptional cases. When we consider how much

else a typical wild animal does with its income besides growing in size and weight, we find it difficult to believe in the " gradual loss of vitality " which seems to Professor Minot to be a general phenomenon of life.

Minot has sought to establish a second corollary of his law,—that as the body grows older there is an increasing disproportion between the cell-substance (cytoplasm) and the nucleus (nucleoplasm). He believes that the cytoplasm increases out of proportion to the nucleoplasm, and thus interferes with the power of growth. It is interesting to find that Minot's views as to the importance of the relation between nucleus and cell-substance, which were first stated in 1890, have found of recent years considerable confirmation. Professor Richard Hertwig of Munich has brought forward a large number of very interesting facts showing the importance of the relation between nucleus and cytoplasm, and has given an elaborate discussion of the whole subject.

Somewhat analogous to Minot's view is that of Kassowitz, who points out that as life goes on there is more and more accumulation of what one may call half-used substances, such as fat, the body becoming, as it were, smothered in the results of incomplete combustion.

Démange, the author of a French treatise on old age, seems to interpret all the phenomena in terms of the degenerative changes in the walls of the arteries. These show hardening or sclerosis, the nutrition of surrounding cells is thereby lessened, and atrophy sets in. As is often said, " A man is just as old as his arteries." There can be no doubt as to the importance of this view, but we wish to know *why* the arterial wall should become sclerotic. Moreover, the theory is far too human in its reference; many old animals show no trace of arterial sclerosis.

According to Metchnikoff, the symptoms of old age

may be for the most part summed up in the conception of atrophy—or insufficient nutrition. This defective nutrition is the prelude to an internal conflict in which the wandering amœboid cells or phagocytes, and one kind in particular, which he calls macrophagous, attack the nobler tissues which are no longer vigorous, which have ceased to produce protective substances, which have been poisoned, or which have been overloaded.

We must also notice the suggestion that the setting-in of old age is due to local exhaustion of certain parts of the bodily machinery with which few of us are familiar—the organs of internal secretion—such as the thyroid gland. These normally furnish to the blood some more or less obscure specific substances without which vigour cannot be sustained, or antitoxin substances, for instance, which enable the body to resist poisons, including those of its own formation. It should be remembered that even an innocent substance like sugar may act as a poison. This view has led to the suggestion of various modern elixirs of life—from injections of common salt upwards—intended to replace the deficiency due to local breakdown. None of the elixirs has as yet proved itself markedly efficacious, nor has any good reason been given why organs of internal secretion should be exhausted sooner than many other organs.

After considering these and other suggestions as to the immediate causes of old age, we feel bound to conclude that in spite of their importance in furnishing descriptive details of the familiar process, they do not throw much light on its necessity. The law of the conservation of energy makes us aware that, defiant as the organism is, arrears are likely to accumulate in the activity of a complex system, but the immortality of the Protozoa shows that this dynamic bankruptcy is not inevitable. We know that a carefully constructed inanimate engine may outlive

three generations of the animate engines who controlled it, and we know that of two organisms, apparently equal in complexity, one may be old in twelve months, and another may be still young in twelve years. It is easy to speak of accumulated debts, of diminished trophic activity of nerves, of hampering superfluity of half-used products and of diminishing activity of internal secretion, of the struggle of parts within the organism and of the limitations to prolonged cell-divisions; but why should it be so at all, and why should the results be so different in different cases?

We are not surprised, therefore, to find a specialist on senility (Dr. W. H. Allchin) declaring: "We do not know why the body, after it has reached a state of maturity and vigour, should gradually decline; why, when once an even balance between tissue-waste and restitution is established, it is not maintained indefinitely." It is easy to understand why individual human beings with poor inheritance, unnatural environment, and vicious habits should exhibit senile involution and die; it is often difficult to understand how they manage to live so long! but these abnormal, though frequent, cases do not touch the biological problem of normal senescence. All the signs of human senility may be seen in a patient under twenty years of age; but this sad fact hardly touches the general problem of normal senescence—which is so elusive.

As we think over such facts as we have hinted at, the suspicion grows strong that we are apt to miss biological truth by being too anthropocentric. Man is in many ways a very artificial organism—he is super-organic. He has an external heritage not less important than that embodied in his germ-plasm; he has often a self-made environment not less important than that which he was born into; he has peculiar functions and habits—both for good and ill—which are all his own; and there is good reason for sup-

posing that the impression of old age which we get from the majority of our aged fellow-beings is very different from what we should have inferred from an impartial survey of animal life.

Perhaps we may recognise three grades :—

a. In many human beings, in not a few domesticated animals, *e.g.* horse, dog, cat, and in some semi-domesticated animals, notably bees, and possibly in some wild animals, the close of life is marked by *senility*. The organism is no longer in full possession of its faculties; more than that, some function or other—notably that of the nervous and sensory systems—has gone out of gear. Intelligence has waned, instincts have ceased to ring true, unified control is lost, the senses are dimmed and dulled, even locomotion becomes impossible, the life is reduced to an existence—an existence which could not be prolonged except under artificial conditions comparable to those of an incubator for premature infants.

b. In a minority of civilised human beings, in some domesticated animals, and in a few wild animals, the decline of life is marked by *senescence*. Growth has long since stopped, and decrease in weight and stature has been going on; there is a general shrinkage, of brain and spinal cord, of spleen, lymphatic glands, and kidneys; the gonads have ceased to be active; there is narrowing or even obliteration of capillaries; the bones become thinner, weaker, and of course lighter; and the corresponding functions are slackened in each case in adjustment to the weakening of the bodily engine. A slight shrinkage of articular cartilages, a slight weakening of dorsal muscles, brings about the normal stoop. A slight atrophy brings about the normal grey hairs—which in this category may be a crown of glory.

c. For many animals it must be said that they reach

the length of their life's tether without any trace of either senility or senescence. They pass their climacteric of vigour, it may be; they may be old in years, but certainly not in structure; they pass off the scene—with a violent shove—victims to violent death. It is impossible to tell whether the vital energies were or were not really impaired, but we know that in many fishes and reptiles, for instance, which have lived long, and have in the end died violently, there is not in their organs or tissues the least hint of senile involution or even of senescence.

In a special category must be ranked the immortal simple animals which never grow old, which disappear directly into other individualities like themselves; of which enough has already been said.

Let us now see if we can make further progress towards clearness by proceeding on a quite different tack, by considering the great variety there is in *the duration of life*. This has often been made the subject of popular remark and of quite fanciful popular estimate. Weismann quotes from Jacob Grimm an old German saying: "A wren lives three years, a dog three times as long as a wren, a horse three times as long as a dog, and a man three times as long as a horse—that is, eighty-one years. A donkey attains three times the age of a man, a wild goose three times that of a donkey, a crow three times that of a wild goose, a deer three times that of a crow, and an oak three times the age of a deer." It need hardly be said that most of these figures are quite fictitious, *e.g.* the estimate of the deer's duration of life at six thousand, and the oak's at twenty thousand. By counting the wood rings in some of the great Californian trees an age of two thousand years and more has been estimated, but some say that more than one double ring of wood is sometimes formed in one year.

In one of his celebrated essays Weismann has sought to show that it is impossible to find the key to the great differences in the ages of animals by any simple reference to size, or to complexity, or to rate of growth, or to rate of life. "The strength of the spring which drives the wheel of life does not solely depend upon the size of the wheel itself, or upon the material of which it is made," or upon its rate of movement. The duration of life has been, in part at least, punctuated from without and in reference to large issues; it has been gradually regulated in adaptation to the welfare of the species.

It is true that large animals usually live long, and that small animals are often short-lived: an elephant may live two hundred years, a horse forty, a blackbird eighteen, a mouse six, and many insects only a few weeks or days. But then a cat or a toad may live as long as a horse (forty), a pike or a carp as long as an elephant (two hundred), a crayfish as long as a pig (twenty), and the sea-anemone "Grannie," which died a natural death in Edinburgh on 4th August 1887, was at least sixty-six years old.

Flourens hazarded the generalisation that the length of life was always five times the period of growth; but the horse, for instance, matures in four years, and may live to be forty or more.

On general grounds, already hinted at, we might suppose that very active animals wear themselves out quickly, while sluggish creatures live long. Instances of trees living for a millennium rise at once in the mind; on the other hand, the male ants live only for a few weeks, while the queen-ant may live for thirteen years, and the workers for several years. Birds are exceedingly active animals, but some of them have a long life; there are cases of ravens, falcons, eagles, vultures, living half more than

a century—in captivity, of course, which would lessen their expenditure of energy.

The clergy have longer lives than other professional men, but most of them live a very active life. St. Antony did not mix much in practical affairs and died at one hundred and five; Titian was all his life about a court, and painted a fine picture at ninety-six.

Perhaps the most astounding fact in regard to human length of life is that brought out in such statistical researches as those of Tarchanow, that throughout the world from equator to poles the duration of life remains on the average the same. This is an astounding fact when we consider the diversity of race, of diet, of occupations, and of surroundings. There are short-lived and long-lived families, for longevity is hereditary; there are life-sparing and deathful occupations and habits; there are pleasant and unwholesome surroundings; yet the average duration of life for different peoples and countries is about the same. This makes us feel that the punctuation of the length of life, which is so diverse among individuals, is, as regards the species, referable to much wider issues than the immediate surroundings, diet, habits, or rate of life. We see no alternative to the conclusion that the clock of human life has been regulated in the course of the ages in reference to the wide issues which we sum up in the conception "the welfare of the species."

We have expounded a general reason why higher organisms must grow old: the perfect self-repairing capacity of the unicellulars is no longer possible when the bodily mechanism is very complex and when reproduction is physiologically expensive. But this natural interpretation of senescence fails to suggest why a dozen different kinds of animals of about the same size and complexity, and with similar modes of reproduction, should

grow old at very different times. An attempt to explain the diversity of longevity by reference to the immediate conditions of life also fails. We have to face the fact that while the rate at which the wheels go round is doubtless very important for individual cases, it cannot be the key to an understanding of the diversity in the average duration of life in more or less similar species. Many sluggish animals, such as molluscs, are short-lived; many active animals, such as birds, are long-lived. Nor can we find the solution in considering the diverse environments, diets, industries, and so on. We are thus prepared for the next step in the argument.

Weismann's theory is that in the course of time, after many experiments, so to speak, the length of life in a species has been regulated in reference to the rate of multiplication and the average mortality. The *punctuation is from without*, not from within; it is Natural Selection that has determined—and that slowly, after grave consideration as it were—where the stops come in: the semicolon of maturity, the colon of senescence, and the full stop of natural death. In other words, the internal constitutional arrangements which secure that an elephant can survive for two hundred years and a freshwater sponge for less than a year, have been gradually wrought out or regulated in relation to the welfare of the species.

Let us take a concrete case: the golden eagle, weighing 9 to 12 lb., is intermediate as regards weight between hare and fox; all three are very active; all three are very complex. But while the hare lives ten years, and the fox fourteen, the golden eagle lives sixty. Weismann says that this has been in the course of time regulated in reference to various big facts of life, *e.g.* that the two mammals are more fertile than the bird, that there is less mortality among the young mammals than among the young birds,

that the young mammals are sooner able to look after themselves, and so on. If the golden eagle matures at about ten years, and lays two eggs a year, "then a pair will produce one hundred eggs in fifty years, and of these only two will develop into adult birds; and thus on an average a pair of eagles will only succeed in bringing a pair of young to maturity once in fifty years." For this reason, golden eagles have a high degree of longevity.

Before we pass to the striking contrast between man and animals as regards growing old, let us consider for a little some of the human signs of old age. What are the signs of normal senescence?

According to one line of interpretation at least, we have one of the sublimest pictures of senility in Ecclesiastes xii. The mind and senses begin to be darkened, the winter of life approaches with its clouds and storms; the arms—the protectors of the bodily house—tremble, the strong legs bow, the grinders cease because they are few, the apples of the eyes are darkened, the jaws munch with only a dull sound, the old man is nervously weak and startled even by a bird chirping, he is afraid of even hillocks, his falling hair is white as the strewn almond blossoms, he drags himself along with difficulty, he has no more appetite, he seeks only for his home of rest, which he finds when the silver cord is loosed or the golden bowl broken.

Let us take a more modern expression. Professor Humphrey had direct or indirect knowledge of the state of the body in five hundred men and women of eighty years of age and upwards, when, in a famous lecture, he summed up as follows:—

"In the normal 'descending' development the relative proportions of the several structures and organs are preserved, while weight, force, and activity are being lowered by a gradual and well adjusted diminution of material and

nutritive activity. During the time that the bones are becoming lighter and less capable of offering resistance, the muscles become, in like proportion, lighter and weaker, and with a narrowing range of action ; and the associated volitional and other nerve-apparatus exhibits a corresponding lowering of energy and force. . . . The weakening of the heart and the diminished elasticity of the arteries provide a proportionately feebler blood-current ; and a lower digestive power and a lessened appetite provide a smaller supply of fuel, enough to feed, but not enough to choke the slowing fires. . . . It is upon the well ordered, proportionately or developmentally regulated, decline in the several organs that the stages which succeed to maturity are safely passed, and that crown of physical glory—a healthy old age—is attained.

" A time comes at length when, in the course of the descending developmental processes, the several parts of the machine, slowly and much, though equally, weakened, fail to answer to one another's call, which is also weakened, when the nervous, the circulatory, and the respiratory organs have not force enough to keep one another going. Then the wheels stop rather than are stopped, and a developmental or physiological death terminates the developmental or physiological decay. . . . Yet, strange and paradoxical as it may seem, this gradual natural decay and death, with the physiological processes which bring them about, do not appear to present themselves in the ordinary economy of nature, but to be dependent upon the sheltering influences of civilisation for the opportunity to manifest themselves, and to continue their work."

Professor Humphrey's summing up may be taken as an authoritative statement of the average state of affairs in human old age, and it is in no way affected by the interesting exceptions that we all know. Thus, for instance,

Montaigne says of his father: "I have seene him, when hee was past threescore years of age, mocke at all our sports, and out-countenance our youthfull pastimes, with a heavy furr'd gowne about him leap into his saddle; to make the pommada round about a table upon his thumb; and seldome to ascend any staires without skipping three or foure steps at once." We have known a venerable naturalist of seventy-five make the ascent of Schiehallion, and walk eight miles besides, without a trace of ill effects. Similar examples are familiar to all, and they represent the ideal, doubtless quite attainable, defiance of senility. They illustrate the contrast between senility and senescence.

Senescence is the normal process of growing old, as we see it in constitutionally strong men who have lived very healthful lives (within or without civilisation), and in those wild animals that live to a great age in natural conditions. Senility is the process of marked degeneration, which is often seen in old age (and sometimes long before it). And the biological fact which seems to us of most importance is the striking one that man and his domesticated animals have almost a monopoly of senility, while wild animals rarely show any trace of it.

It may be said that most wild animals die a violent death in the majority of cases before they exhibit even senescence. But some live to a great age, and the important fact is the practical absence of senile degeneracy, except in relatively unimportant parts, such as the teeth. Apart from captive carp and the like, which must be discounted, fishes that have demonstrably lived for a great many years (as the rings on their scales, bones, and ear-stones show) do not exhibit any trace of senile degeneration. Dr. F. Werner, an expert student of reptiles, emphasises the fact that even in giant specimens of crocodile and snake "no trace of senile degeneration could be detected."

In concrete illustration of old age phenomena, let us take Metchnikoff's account of the hair turning grey in man, and his account of the state of a very old captive parrot. Turning grey can hardly be called more than a phenomena of senescence; the parrot showed senility, so that the two cases do not quite illustrate the contrast that usually obtains between man and beast in old age.

In almost all animals, from sponges to mammals, there is, within or apart from the vascular fluids, a bodyguard of wandering amœboid cells, technically called phagocytes. It is well known that they perform many functions both in health and in disease: they form a bodyguard, struggling with invading microbes, surrounding and engulfing irritant particles, transporting useful material, helping to repair wounds, aiding in the regeneration of lost parts, and in metamorphosis, and so on. To the pathologist, "phagocytosis" has become a word of comfort, and perhaps there has been some exaggeration of its importance. But no one can deny that the phagocytes play an important and versatile part in the vital economy.

If we hold a hair against a strong light we see at once a distinction between a lighter central portion—the medulla, and a darker peripheral portion—the cortex. Both parts are built up of cells, but the medullary part is the more living of the two. Metchnikoff discovered that the disappearance of pigment from hair beginning to turn grey is due to the intervention of phagocytes. These amœboid cells appear in the medullary part of the hair and make their way out into the cortex, where they absorb the pigment granules, which they then remove from the hair. In a hair beginning to turn white, there are many phagocytes laden with pigment—especially about the root of the hair. In absolutely white hair—the colour of which is due to gas bubbles—there are no phagocytes with

pigment or only a few. "It is thus indubitable," Metchnikoff says, "that the phagocytes of the hairs swallow up the granular pigment of the cortical layer and transfer it elsewhere, the result being the complete whitening of such hair." This interesting discovery brings the whitening of the hair into line with other processes in which phagocytes play an important part. If it should be insisted that even here there is senile atrophy, we are quite willing to yield the point—the contrast would remain, however it is phrased, between relatively trivial and superficial changes in old age and others which imply the thoroughgoing degeneration of important structures.

Something more serious than an absorption of decorative pigment was revealed in Metchnikoff's study of an aged parrot. It is known that these big-brained birds often live to a great age; for, although we may not accept Humboldt's famous story of an aged parrot that spoke the aturic language of a tribe of American-Indians for years after there was any human survivor able to understand it, we have to recognise the validity of other records showing that parrots may outlive their long-lived owners and exceed even fourscore years. It was a veteran, belonging to the species *Chrysotis amazonica*, of which Metchnikoff made a careful post-mortem, with the assistance of Mesnil and Weinberg, and she must have been over eighty when she died. During her declining years the captive was feeble and senile; but the striking fact was that a thorough investigation of the tissues revealed little, except along one (very important) line, that could be called degenerative or deathful.

The post-mortem report on the aged parrot informs us that the liver was slightly fatty, but showed no hint of cirrhosis or any other disease; the kidneys were tending towards fatty degeneration, but showed

no sclerosis or hardening; the muscles and the heart were quite normal, and so on. It goes without saying that we must not generalise on one parrot, and very few aged parrots have been scientifically utilised; but the fact is quite clear—that this octogenarian was very sound in most of its organs. It would have passed even a strict Insurance Examiner on all points save one, and that happened to be detected because the scientific eye was predisposed to see.

Only in the fore-brain was there anything very note-worthy—its nerve-cells were in many places surrounded with nerve-devouring phagocytes. These "neuronophagous cells" are well known in the brains of patients suffering from certain neurotic diseases and from persistent intoxication; they are also frequent in the brains of old men and old mammals, but the authors never saw a case so marked as that of this aged parrot. There seemed to be "an intense phagocytosis"—the brain was being literally "devoured" by the "neuronophages." The noblest elements of the organisation were falling victim to cells of the most primitive type—comparable to the immortal amœbæ. Here we have a most interesting case of senility—and yet, only local cerebral senility—in a captive creature. It is a supplement to what we have already noticed in connection with the brains of bees.

After this illustration, intended to bring out the contrast between normal senescence with relatively trivial changes and senility with marked degeneration or involution of important structures, we venture to submit four theses,—that few wild animals of great age show *any* senile degeneration; that few wild animals of great age show more than signs of general senescence; that many very old men show no signs of senility, but only of senescence; and that, as all the so-called signs of human senility may be found illus-

trated in young men under twenty, we may regard senile degeneration as an unnecessary incident of old age !

Let us face the question: Why should wild animals show so little trace of senility, which is often marked in domesticated or captive animals ? why should they rarely exhibit more than a slight senescence, while man often exhibits a bathos of senility ?

In reference to the contrast between wild animals and those tamed or in captivity, we have to remember that the former seem usually to die a violent death before or after old age has set in, but almost always before there has been time for senility. From such violent death man more or less protects the pet horses, dogs, cats, etc., whose life has become entwined in his affections. Furthermore, while natural death is due to the accumulation of physiological bad debts, the character of the old age depends upon the nature of these bad debts. Some are much more unnatural than others; they are much more unnatural in tame than in wild animals.

As to man, in particular, let us recall a few facts which may explain why he is unhappily notorious as the best illustration of senility. (*a*) Being sheltered by Reason from most of the extreme physical forms of the struggle for existence, he can live for a long time with a very defective hereditary constitution, which may end in a period of undesirable senility. (*b*) Endowed as he is with Reason—the capacity for handling general ideas and regulating his conduct in reference thereto—man, especially in highly civilised communities, is very deficient in the resting instinct, and seldom takes much thought about resting habits. A simple creature exhausts its stores of internal fuel, the nervous system gives the signal "Hunger" or "Fatigue," and infallibly the simple creature will eat or rest if it can. Its brain is not disobedient. In higher

animals, however, and especially in man, the matter is much more complicated. The signals for stoking or resting are plainly given, but some higher nerve-centre countermands them. We disregard the moral of the worker-bee's life. (*c*) The artificiality and injuriousness of many human activities and environments must necessarily affect the character of the physiological bad debts which lead on to natural death. The death is inevitable; but just as there is more than one kind of bankruptcy, so there are different forms of old age. Everything depends upon the nature of the bad debts. We may have an old age such as Cicero praised, or one whose days are labour and sorrow. As there is no power of regeneration in the nervous system—for, except in very rare cases of injury, we never get any new nerve-cells after we are born—and as it is especially the wearing out of the nervous system which makes the down-grade of life often ugly, and as it is pre-eminently by rest and change and a quiet mind that the nervous system is kept young, we come again to the old commonplace, "Let us be aisy; and if we can't be aisy, let us be as aisy as we can." (*d*) In contrasting man and the animals, we have also, of course, to remember that in many cases there has come about in human societies a system of protective agencies which allow the old to survive through a period of prolonged senility. We cannot do otherwise in regard to those we love; but it is plain that our better ambition would be to raise the standard of our vitality so that, if we have an old age, it may not be more than senescent.

After writing these hard sayings, we were relieved to read what Dr. Humphrey said in 1885: "Through the growth of this germ (of sympathy) it was given to man to introduce a new factor into the economy of Nature, and by forethought, by mutual co-operation, and by care for others, which are the very essence, at any rate the very best

feature, of civilisation, to prolong life when by this very forethought and sympathy life had become more valuable, and when the prolongation of it had consequently become more desirable; and scope was thus afforded for the carrying out of these descending or senile developmental processes which must have been nearly dormant in the earlier periods of human existence." "It is not to be expected that this good seed should be without a blending with tares; and the scope thus given for the fuller development of the physiological processes gave scope also for the development of the pathological processes, and enabled the various diseases to spring up and take their course, afflicting not man only, but those animals also which come under his fostering or protecting influence."

"It may therefore be said that the prolongation of life into and through the periods of decay, and into and through the processes of disease—indeed almost, if not quite, the very existence of decay and disease—are the result of human forethought and sympathy. In other words, decay and disease are, by civilisation, substituted for quick and early death." This is a forcible and authoritative statement, which leads us to doubt whether the humane policy, which makes so much of the individual, is not in some respects prejudicial to the best interests of the race.

What have we to suggest? Certainly no elixir vitæ, but a humdrum, common-sense prescription, the common property of the oldest and the newest physicians, which does, however, gain some added force from the biological facts that have been submitted. Closer touch with Nature, more open air, more change of environment, more versatility of function, more effort to secure the lines of activity that are organically most suitable and, therefore, most effective,

less artificial stimulation, less "pressing," as golfers say, stricter avoidance of nerve-fatigue, more resolute cultivation of resting-habits, an effort to heighten the standard of vitality rather than an effort to prolong existence—such are some of the conditions of *remaining young*.[1]

[1] I have to thank the editor and proprietors of *The London Quarterly Review* for kindly allowing me to utilise in the foregoing study an article on "Growing Old" which I contributed several years ago.

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DARWINISM AND HUMAN LIFE

By PROF. J. ARTHUR THOMSON, M.A.
University of Aberdeen

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The book bears this dedication:

DEDICATION

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